Willson Consulting
willsonconsulting26@yahoo.com.au
0448 430 980

Review: Corrections to IPEN F3 Position Paper –POPRC-14

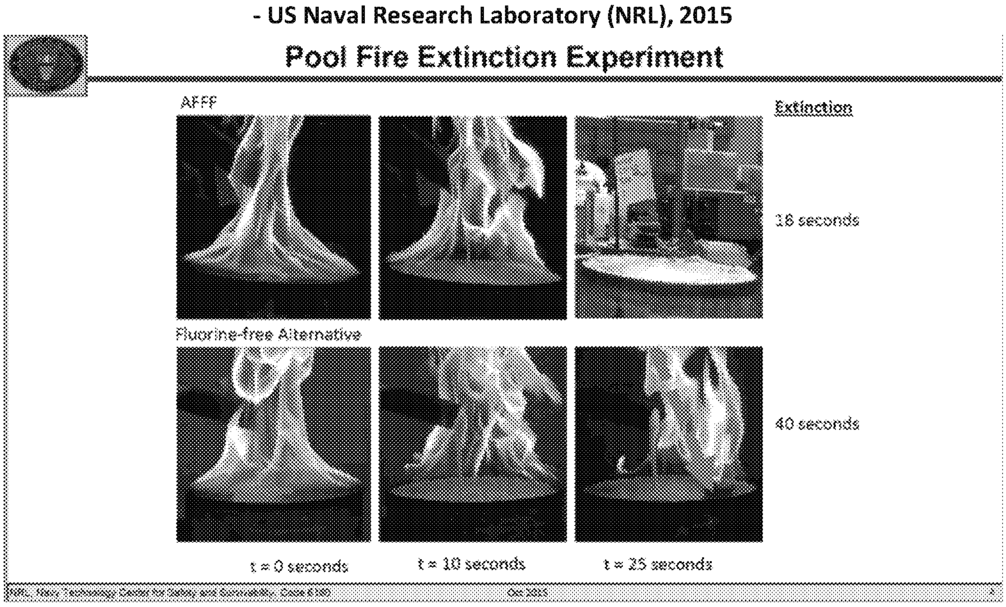
Prepared for:

Environmental Protection Authority New Zealand - Firefighting Foam Workshop, Wellington New Zealand.

15th November 2018

IPEN F3 Position Paper available at: https://cswab.org/wp-content/uploads/2018/09/Fluorine-Free-Foams-IPEN-Paper-POPRC-14-Sept-2018-FINAL.pdf

Comparison AFFF v Fluorine Free Foam Extinguishment on same pool fire - US Naval Research Laboratory (NRL), 2015



Source: Hinnant K, et al 2015 - "Evaluating the Difference in Foam Degradation between Fluorinated and Fluorine-free foams for Improved Pool Fire Suppression," US Naval Research Laboratory, ARL-TARDEC Fire Protection Information Exchange Meeting, Aberdeen Proving Ground, MD, October 14, 2015.

How Can IPEN's F3 Position Paper Be Correct?

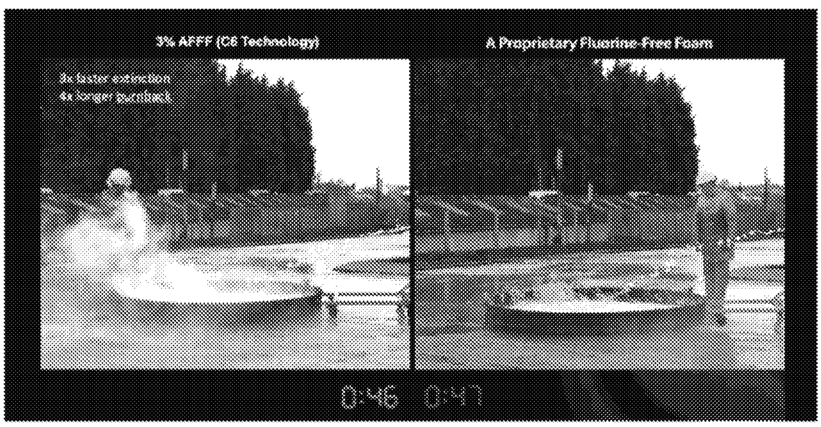
Executive Summary

In response to this IPEN F3 position paper intended for UN's Stockholm Convention POP Review Committee, plus foam users, regulators, observers and the public, Willson Consulting set out to correct the multitude of misconceptions and errors contained within, recently highlighted by the USA's Fire Fighting Foam Coalition in their recent strong rebuttal to UN. Discussion of this complex topic should be about providing our best fire protection, while protecting our environment - using factual evidence and truths, not "fake news" – **lives depend on it**. This F3 paper rejects proven scientific facts, claiming somehow "*Fluorine Free Foams can do all that Fluorinated foams can do*", without critical or substantiating verification. This strong rebuttal uses scientific evidence to expose these errors, of which there seem to be far too many to be accidental.

F3s can prolong fires endangering life safety

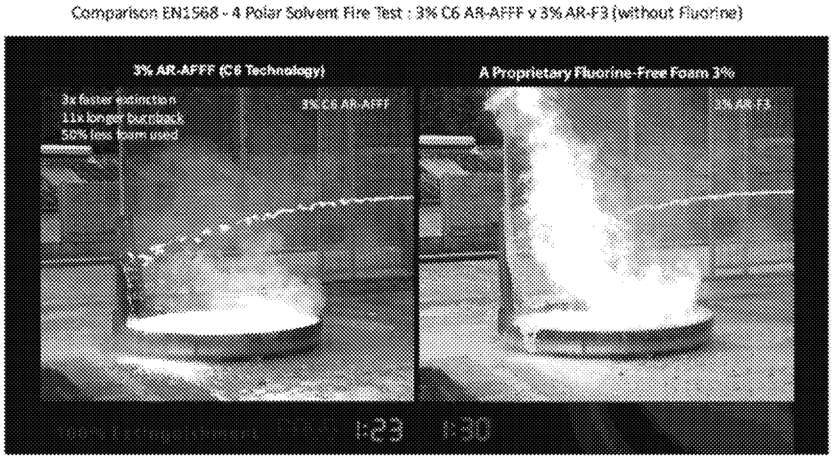
Over 60 concerns of misleading and incorrect statements are discussed in this full review. For example, Section 1.4, p22 claims **"There is absolutely no evidence, anecdotal or otherwise to support Fluorine-free foams endanger life safety for both fire fighters and members of the public.",** which is proven to be false. BUT …significant differences are evident in comparative testing on volatile fuels like Jet A1, gasoline and polar solvent fuels - US NRL (cover) and elsewhere:

Comparison ICAO Level B Jet A1 Fire Test : 3% C6 AFFF v 3% F3 (without Fluorine)



Source: Angus Fire, 2013 – You Tube Comparative video tests "AFFF/AR-AFFF v Fluorine Free Foam (F3)", on ICAO Level B and EN1568-4 tests - evidence faster extinction, superior burnbacks and less agent usage with short-chain C6 fluorosurfactants, www.youtube.com/watch?v=3MG2fogNfdQ

Comparison EN1568 - 4 Polar Solvent Fire Test : 3% C6 AR-AFFF v 3% AR-F3 (without Fluorine)



Source: Angus Fire, 2013 – You Tube Comparative video tests "AFFF/AR-AFFF v Fluorine Free Foam (F3)", on ICAO Level B and EN1568-4 tests - evidence faster extinction, superior burnbacks and less agent usage with short-chain C6 fluorosurfactants, www.youtube.com/watch?v=3MG2fogNfdQ

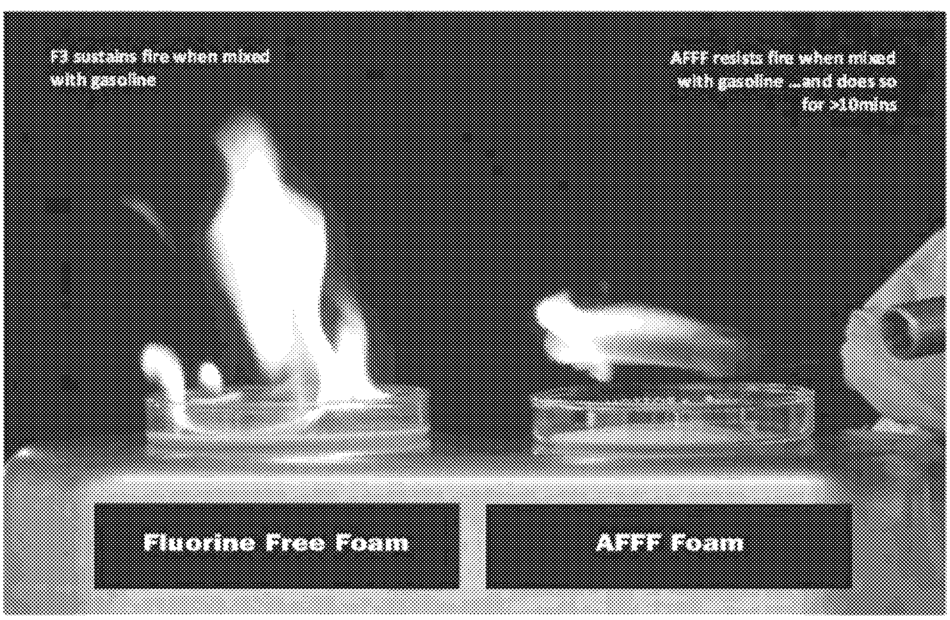
These stills comparing F3 v C6 AFFF fire testing, verifies superior extinction speed and burnback resistance of fluorinated foams. Watch the video:www.youtube.com/watch?v=3MG2fogNfdQ

Such small scale AFFF fire performances have been extensively verified at large-scale up to 3,000m^2 fire area (equivalent to 62m dia. storage tank) confirming effective application rates protect life safety from fires in Major Hazard Facilities (MHFs). Design standards like NFPA11 were founded on such verified performances with 100% safety margin, we take for granted. BUT …***Is this true of F3s? Where is the large-scale verification test data?***

F3s without fuel shedding and poor vapour sealing –place lives at increased risk

AFFF development was accelerated after the USS Forrestal aircraft carrier disaster in 1967 to avoid it happening again. 134 lives tragically lost, 161 injured, 21 planes destroyed and 40 planes damaged, when a protein fluorine free foam – like modern F3 versions – without fuel shedding ability and poor vapour sealing, proved unsuccessful. Let's be more cautious before too hastily winding that clock back? Especially when US research in 2012 showed modern F3s mixed with fuel was still flammable. Watch" Foam Flammability!" video www.youtube.com/watch?v=IuKRU-HudSU proving beyond doubt that F3s pick up fuel, sustain ignition, can flashback suddenly, placing life safety at unnecessarily increased danger. Testimony by two leading fluorine free foam manufacturers at USA's Washington State House Environment Committee hearing in Feb.2018, confirmed these facts, leading to PFAS foam exemptions to PFAS restriction legislation for MHFs (ie. airports, military, oil refineries, fuel terminals, chemical plants).

Comparison F3 v AFFF equally mixed with gasoline and placed in a petri dish. When a flame is introduced above the foam blanket, F3 immediately ignites and sustains ignition until it burns away, while AFFF resists ignition, …and does so for more than 10 minutes.



Source: Jho C, 2012 – You Tube Comparative video tests "Flammable firfighting foams - evidence superior burnback when AFFFs are used on volatile fuels like gasoline , www.youtube.com/watch?v=IuKRU-HudSU

This lack of fuel shedding and poor vapour sealing ability by F3s was endorsed by Schaefer's own 2008 research - leading F3s proven only 30% as effective as AFFF at sealing volatile fuels like unignited gasoline. US Naval Research Laboratory in 2015 showed F3s 90% less effective than AFFF on warmed gasoline, more typical of summer conditions, and by a 2013 major unignited gasoline spill near Sydney. Fluorocarbon surfactants provide critical and unique fuel shedding and vapour sealing capabilities necessary to achieve rapid, reliable, efficient, fire control and extinction to best protect life safety, especially in MHFs, where large volatile in-depth fuel fires using forceful foam application is frequently inevitable.

18 of 19 supposed "Myths" are FALSE

A similarly disturbing rejection of scientific evidence in 18 more supposed "Myths" ensues. A bizarre "reversalism" of headings, where virtually all supposed "Myths" are factually correct, with many claimed "Reality" positions, blatantly false. Each are ACCURATELY addressed, and individually CORRECTED in the full detailed report. Fluorine Free Foams (F3) have an important role to play in protecting smaller fires where higher application rates can be used, and where the foam cannot be contained, like many Fire brigade call outs, firefighter training and system testing. But are proven NOT well suited to large volatile fuel in-depth fires where foam is forcefully applied – like all MHFs.

2 similar aircraft fires: different foams = different outcomes

How does a June 2016 Boeing 777 major engine fire in Singapore get extinguished in 2 minutes using fluorinated foams, all passengers and crew were disembarked safely, the plane returning to service some weeks later, but an August 2016 Boeing 777 detached engine fire in Dubai burned for 16 hours under foam attack until the aircraft was destroyed? Miraculously all passengers and crew escaped before the fire took hold. A brave firefighter tragically died in a fuel tank explosion 9 minutes after the crash. ***Were lives at increased risk?*** IPEN's Appendix 1 confirms Dubai International Airport as a major F3 user, apparently since 2011, with recent fire truck F3 samples passing routine laboratory testing. ***Why is the final investigation report still not issued to explain this firefighting failure - over 2 years later?***

Dubai B777 fire burned for 16 hours.

Why did a July 2016 planned F3 ICAO Level B demo get substituted last minute by a C6 AFFF in 32°C humid Singaporean conditions? Because "***too many environmental factors were not under our control to do F3.***" This same fire was unable to be extinguished twice using F3 the day before in 32°C conditions, catching the fuel separator alight - indicating virtually no fire control. C6 AFFF provided progressive control and extinction without edge flickers, despite humid 32°C conditions.

F3 does not prevent costly clean-up

F3 use doesn't prevent extensive clean-up requirements during incident use - ***because PFAS usually form breakdown products in firewater run-off***, likely exceeding water quality values, requiring collection, containment, analysis remediation – but expect 2-3 times more volume!

'The problem with remote yet potentially catastrophic risks - they do sometimes materialise, then otherwise very reasonable decisions start to look very UNreasonable, ...even criminal'

If IPEN's F3 Position Paper distortion of the truth bothers you, please read on...and make up your own minds about the many clarifications, corrections and factual references within, extending knowledge, in this complex area of inter-related impacts and consequences.

Mike Willson, Director & Technical Foam Specialist, Willson Consulting. ©12th November 2018

Introduction:

In response to this IPEN F3 position paper, we set out to correct the misconceptions and errors contained within. This review document is designed to help readers understand the short-comings of this IPEN paper, which uses many misleading statements, untruths and false assertions, seemingly intent on distorting the truth with fake news. **This strong rebuttal uses scientific evidence to expose these errors, of which there seem to be too many to be accidental.** Misleadingly influencing the UN Review Committee's thinking - and any others reading this IPEN F3 position paper – by rejecting scientific research, deliberately deceives them, **which is wrong.**

Discussion of this complexity with inter-related inter-actions and consequences should be about facts. What provides the best fire protection to **save lives**, minimises adverse environmental impacts from the **whole incident** (not just the foam concentrate in isolation), using factual evidence and the truth – **as many lives could be depending on it!**

F3s have a limited role to play

F3's do have an important (but limited) role to play, particularly in protecting smaller fires where higher application rates can be used effectively and foam discharge cannot be contained, like many Fire Brigade call outs, and where lives should not be at risk, like firefighter training and system testing. Its focus should be in areas where life safety is not being compromised, and incident escalation is unlikely. **BECAUSE F3 has not been proven effective for MHFs, or in large scale testing as it suffers from fuel pickup when mixing with fuel, quite poor vapour sealing and increased escalation potential.** This can rapidly lead to unpredictable flashbacks, re-ignition and potentially sudden incident re-involvement, **potentially placing communities and life safety at unnecessarily increased danger.**

F3s shown unreliable for large volatile fuel fires – ie MHFs

F3 is unable to provide adequate assurances of reliable and efficient capability for use in **Major Hazard Facilities (MHF) fires - by which we mean airports, helidecks/pads, military applications, oil and petrochemical refineries, fuel terminals, major fuel transportation (rail, ship, pipeline), Chemical, pharmaceutical and major industrial plants where large quantities of fuel (particularly volatile fuels) are stored and used in various production processes. This can include mining, offshore platforms, production vessels, cruise ships and large vehicle transporters/ferries, ports receiving them, paint plants, major flammable liquid distribution terminals, even large DIY/automotive warehouses**. **These MHFs should include anywhere involving large volumes of volatile fuels, where the adverse consequences of fire could unnecessarily increase danger to life and community safety. This increased severity may come from increased flashback risks, slower fire control, delayed extinction, more agent use, increased firewater runoff, increased risk of escalation to neighbouring properties or communities, if …or when, fire strikes.** Application rates used in small scale fluorinated foam and AFFF fire testing have been extensively verified at large-scale up to 3,000m^2 fire area (equivalent to 62m dia, storage tank surface area) **where similarly low application rates were proven achievable, effective and reliable**. This led to current design standards based on fluorinated foam performances we rely on today, typically with a 100% safety factor (eg. NFPA11) which we also now take for granted. UL 162 recognises the need for a higher test application rate when using F3s. *Where are the revised design standards which take into account the inferior performances we are seeing from F3 agents?*

Where is the F3 performance data at large scale?

There appears to be no such evidence base for F3 agents at large-scale to verify the small scale *performances?* **We should perhaps remind ourselves of the <u>134 lives tragically lost, 161 people injured, 21 planes destroyed and 40 planes damaged in the 1967 USS Forrestal aircraft carrier fire, where fluorine free foam use led to accelerated development of reliable fast acting AFFFs, to prevent such a tragedy recurring in future</u>** (see Myth 19, p27 below). *Shouldn't we be more cautious and careful before too hastily winding that clock back?*

This IPEN paper seems to fall into a disturbing populist "**fake news**" category. It seems to reject proven scientific facts while spuriously claiming that somehow "*Fluorine Free Foams can do all that Fluorinated foams can do*", **both misleading and incorrect - without any critical verification**. It also disturbingly seems to suggest that F3 agents (ie those supposedly completely free of fluorine!) should now be able to "contain up to 10ppm fluorine". *Surely the Fluorine content proposed - 10ppm simply re-qualifies F3s, as AFFFs?*

Navigating this Review more easily…

To make it easier to dip in and find claims of concern **that may be of particular relevance or interest to you,** these corrections are sequentially listed as they appear in the IPEN document, but are also labelled with **specific categories of interest.** Each Claim has its label no./Category (in purple) identified at the top of the left column throughout the tabulated section for quicker scanning ie:

1. Operational effectiveness (1. OpE)
2. Social-economic-health impacts (2. SEH)
3. Fire performance (3. FP)
4. Environmental impacts (4. EI)
5. Certifications/Standards (5. C/S)
6. Legislation (6. L)
7. Free of fluorine (7. FoF)
8. PFAS Contamination/remediation (8. C/R)
9. and an "Others" category (9.Oth) - catching those not falling into 1-8 above.

<u>This Key to following sections</u> is also designed to make things quicker and easier to find: normal text = black; **bold =important sections** …sometimes **<u>underlined;</u>** *Quotes = italics*; pertinent Qs = *Blue?*; reference nos: = red eg.2015 Firefighter study[7] ; yellow highlight = Claim of particular concern; all intended to make scanning, reading, finding particular items of interest - including references- somewhat easier to navigate… hopefully! We sincerely trust you find benefit and facts in this document, which is its main purpose… to help put the record straight.

Category: IPEN Section/ Page no.	Claim?	CORRECTION
3. FP: Intro. P4, para 1	*"**We believe** that it offers a fresh perspective from experts in the field who have direct experience and knowledge concerning the efficacy of fluorine-free firefighting foams as safer substitutes for AFFF."*	**Misleading.** This document should not be about "*believing F3 offers a safer substitute to AFFF*"...**it should be about scientific facts and verification – whether this is, or IS NOT, factually correct. Lives will depend on it. We should all be aiming for the BEST fire protection to save lives, protect our communities, environment and workplaces from harm.** **Evidence regarding the addition of unique fluorosurfactants required by AFFFs to deliver fast acting fuel shedding vapour sealing fire performance beyond the abilities of F3 are contained in numerous scientific research papers, irrefutable fire test comparisons, verification of comparative F3 v fluorinated foam fire performance at large scale**[21, 66-74,77-79,115,116,] **as well as small scale fire tests**[17,30-32,82]. These large tests[21, 66-74,] were used to justify the design standards applicable today (eg. NFPA11) that relate to fluorinated foam's proven fire performance – **all highlighting major misleading and false assumptions seem to have been made by this IPEN document**. **Interestingly no mention is made in IPEN's document of the major projects both NFPA and UL currently have underway to verify F3 performance**[145]**. These organisations recognise the need to investigate modifications and changes they consider necessary to existing firefighting foam system design standard application rates for F3s**, because they behave differently to AFFFs and other fluorinated foams. This would allow for more widespread and safe use of F3 agents, where that is considered acceptable in future. Currently there are no clear and verified guidance values which are known to work effectively at scale and in dedicated fixed foam systems. **An acceptance that the evidence available confirms F3 are not a "drop-in" replacement for AFFFs**[46,104,140] **or** other fluorinated foams and require a different set of design rules to adequately protect life safety into the future. **UL 162 standard already requires a 6.5L/min application rate for F3s compared to 4.1L/min for AFFFs to pass their tests**, in recognition of poorer fire performance[89].Until these new rules are established, **it would be unwise and potentially unsafe to change fixed foam systems**

		<u>designed for fluorinated foam agent usage to any F3 alternatives, without a comprehensive and rigorous risk assessment</u>[46,104,140] **<u>and adequate scale testing to verify effectiveness</u>** for specific applications at specific application rates.
2. SHE: Intro. P4, para 1	*"**We hope** that the evidence presented in the paper will contribute toward decisions that will prevent further harm to the global environment and human health caused by the dispersive contamination associated with continued production and use of fluorinated aqueous film-forming foams (AFFF) used in firefighting."*	**<u>Misleading.</u>** Little evidence is presented to verify this "hope" will actually deliver safe F3 protection of people's lives and critical infrastructure. *Suggestions that UNIDO's estimated 5% of global PFAS production*[1] *used in firefighting foams is able to cause more potential harm to the global environment than the 95% of other PFAS uses, which currently enter our environment every day of every year, year in year out through WWTPs and landfill leachate, without any regulatory restriction, seems far-fetched?* Particularly when irrespective of major changes to current foam management practices, **<u>PFAS is also shown to still emanate from historic fire training areas, where F3 has been used for years, or even when it rains</u>**, as well as the recent Footscray chemical fire.[2-5]. *See also p7 bullet 3 below.* Current changes to management practices are designed to prevent our PFAS legacy perpetuating[39-42], and Australian Government human health guidance[6] confirms "***<u>There is no current evidence that supports a large impact on an individual's health</u>."*** from PFAS chemicals …and ***"In particular, there is <u>no current evidence that suggests an increase in overall cancer risk</u>.*** We will still have to manage and remediate those highly contaminated sites effectively[44-55] to reduce high levels of PFAS in the source areas from spreading more widely, while collecting, containing and remediating runoff containing PFAS levels above those allowed for discharge to the environment, with subsequent destruction of ALL collected PFAS.
2. SHE: Intro. P4, para 2	*"New insights about the adverse health effects of PFAS chemicals at exquisitely low exposure levels, including PFOA and PFHxS, are coming to light in the peer-reviewed scientific literature."*	**<u>Misleading.</u>** Claimed "**adverse health effects of PFAS chemicals**" have been **<u>shown to be overblown by the 2018 Australian Department of Health expert PFAS review panel</u>**[6] concluding "***There is no current evidence that supports a large impact on an individual's health." …***and ***"In particular, <u>there is no current evidence that suggests an increase in overall cancer risk</u>.*** *The main concerning signal for life-threatening human disease is an association with an increased risk of two uncommon cancers (testicular and kidney). These associations in one cohort*

		were possibly due to chance and have yet to be confirmed in other studies." The Australian 2015 Firefighter study[7] **confirmed increases in Testicular cancer were likely caused by inhalation and skin absorption of volatile breakdown products of the fire (in smoke particularly), some of which are proven carcinogens like Benzo(a)pyrene**, when 79% of all firefighter responses were to structural, vehicle and bush fires where fluorinated foams are not used. It is also likely these "new insights" preferentially refer to long-chain PFAS including PFOA and PFHxS which are already under consideration for POP listing by the Stockholm Convention[8,9]. It is **misleading to lump all PFAS into the same bucket as proven PBT substances, when short-chain ≤C6 PFAS are categorized NOT Bioaccumulative and NOT Toxic**[10]. NICNAS IMAP 2016 Human Health Tier II C6 Assessment's Occupational and Public Risk Characterisations[11] also co-incides with the Department of Health' Expert panel view, concluding: ***"Therefore, the chemicals are not considered to pose an unreasonable risk to workers' health."*** and ... ***"the public risk from direct use of these chemicals is not considered to be unreasonable."***

1. OpE: Intro p4, para 3	*"Based on the evidence presented in this paper concerning the availability, effectiveness, and certifications of fluorine free firefighting foams, we affirm that no exemptions for continued production and use of PFOA and its precursors or PFOS in AFFF should be recommended and* ***no exemption should permit continued use of existing AFFF stockpiles containing PFAS substances****."*	**Misleading and false.** Firstly, there is **no overwhelming evidence** supporting the effectiveness of Fluorine Free Foam (F3) agents, particularly at larger scale on volatile fuels and in-depth fires – beyond small indicative fire tests. *Where is the evidence?* This is particularly concerning when **ICAO diluted its Level B and Level C fire tests in 2014**[12], **which has allowed a number of low quality AFFFs and F3s to pass, when previously they failed**. Secondly, **ICAO Certificates have been issued for F3 agents certifying a PASS**[13], **when unacceptably low ambient conditions of 0°C were somehow "accepted" as meeting the ≥15°C ambient testing requirement**. *Why was this Level B foam example given a pass? ...when it clearly FAILED the required test criteria? Presumably similar errors could have occurred or be occurring at Level C also?* *Does this uphold principles of ensuring safest fire protection for our travelling public, aircrew, emergency responders and airport staff? ...as one might reasonably expect from ANY responsible employer?* *'The problem with remote yet potentially catastrophic risks - they do sometimes materialise, then otherwise very reasonable decisions start to look very UNreasonable, ...even criminal'* **Appendix V of this IPEN paper contradicts many claims within the rest of this IPEN document** by clearly stating on p59 "***The poorer performance of F3 in this case can be overcome with a higher application rate***." And "***At low application rates (approximately 4 l/min/m2), a "gentle" F3 application is recommended due the known "fuel pickup" effec***t."
2. SHE: Intro p4, para 4	*"We further caution that replacement of other per-and polyfluorinated substances in AFFF including short-chain PFAS, would be regrettable substitutions that perpetuate harm to the environment and human health."*	**Misleading and false**. There is **no evidence** suggesting that short-chain PFAS ***"perpetuate harm to human health and the environment"***. **C6 PFHxA has a human half-life of 32days, is excreted through the urinary system**[14]**, and categorized as NOT Bioaccumulative and NOT Toxic**[10] (compared to long-chain C8s confirmed PBT with human half-lives of 3.5-8.5 years)[15]. **C6 AFFF agents are also typically at least 10x less toxic than F3s to aquatic organisms** in the environment as shown by Eurofins 96hr LC 50 fish toxicity comparative data for neat concentrates, presented at a Singapore Aviation conference in 2016, **showing 3 different F3 3x6 agents with 38, 110 and 200mg/L** compared to 1x3% AR-AFFF at

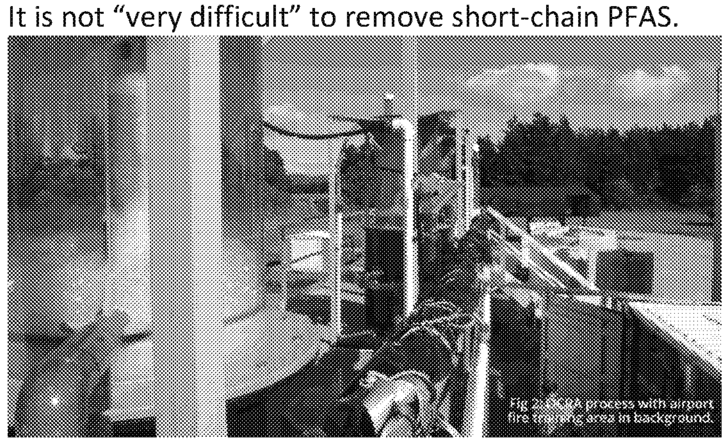
		3,125mg/L, **AFFF 3% at 3,900mg/L**, AFFF1% at 6,300mg/L and FFFP3% at 7,500mg/L[16]. **Significantly less AFFF foam usage is also likely to be required in a given size volatile fuel fire incident using C6 AFFF compared to F3s[17], reducing the consequential BOD loading to the environment[3,18], reducing harm to the environment and human health.** *See also p2 para 4 above.*
9. Oth: "Expert" Panel, p5&6	*Heavily biased pro -F3 Panel*	**Misleading.** *Are we seeing some concerning parallels with the 2014 "Madrid Statement"[19]?* A candid and accurate analysis of which, by Joslin 2014 highlighted[20]… "***Similarly it should be stressed that the Madrid Statement is simply the view of a lobby group; no more, no less****. Significantly it does not contain signatories from the chemical industry, the fire safety sector or government research groups. Nor does it enjoy the support of individual nations or influential collectives such as the World Health Organisation (WHO) or the Stockholm Convention on persistent organic pollutants (POPs). Rather than attracting backing from a truly wide ranging support base****, it relies heavily on individuals dedicated to working on environmental and sustainability issues****. In other words, only those with a somewhat vested interest in the subject and consequently representing a selective part of the scientific community. "Where are the researchers and experts seeking to deliver safe fire protection?* Most members of the IPEN "panel of experts" seem to be propagandists for F3 - either conduct work for, or have worked for 3M, Solberg, or their own F3 product promotions as a perceived marketing advantage, **rather than demonstrated equivalent effectiveness to AFFFs**. They are well known for their pro-F3 biased stance and most are questionable as "balanced experts". Even at a time when Ted Schaefer's own 2008 Newcastle University research[17] confirmed "***…best F3 provides only 30% durability of AFFF on gasoline",*** supported in 2015 by NRL[82] testing**.** Consequently, **this IPEN document does NOT show a healthy balance of views, rejects factual scientific research, is misleading and distorts the truth**. Several members – in particular Roger Klein, Ted Schaefer, Nigel Holmes, Michael Allcorn, Gary McDowall, Thierry Bluteau, Niall Ramsden, and Ian Ross are **trying overly hard to claim F3 as a suitable AFFF replacement without rigorous justification, including for Major Hazard Facility(MHFs) usage,** when there is **insufficient evidence of low application rate** large scale testing to support this view, and **lives are being put at unnecessarily increased risk of premature termination**.

		All their evidence relies on small scale tests of 1-350 m^2. Fluorinated foams have been verified on much larger scales up to 3,000m^2 (32,500ft^2) fire tests[21] on multiple occasions to verify low application rate effectiveness also shown effective in small scale testing. **<u>Solberg's own leading research chemist Mitch Hubert under oath</u>** at the Washington State testimony hearings in Feb2018[22,23], confirmed beyond doubt that" …***although suitable for shallow spill fires, <u>when F3s plunge below the surface in fuel in-depth fires it picks up fuel, comes to the surface and actually burns</u>***." (Shallow spill fires are defined as <25mm fuel depth). Jho's 2012 foam flammability research proved it[31.32]. **This Washington State legislation was passed to exempt PFAS based AFFFs from restriction for MHFs, defined as Airports and Military applications, Oil refineries, fuel terminals, chemical plants** (except during training) in March 2018[24].
1. OpE: Exec Summary p7, bullet 1	*"… have continued to advance and expand in use dramatically since their initial development in the early 2000s by Ted Schaefer working for the 3M Company and are now well-established as high-performance firefighting agents."*	**<u>Misleading and factually incorrect.</u>** The **world's first modern Class B F3 agent public launch and demonstration to foam users was of Angus Fire's Syndura at RAF Manston UK**, on 12th June 2002[25]. It was launched with concerns over potential flashbacks and poorer vapour sealing ability than AFFFs, later confirmed as an F3 characteristic by Schaefer's own 2008 research ***"…best F3 provides only 30% durability of AFFF on gasoline".*** Comparative testing also showed Syndura performed as well if not better than Solberg's RF6 F3 agent, particularly with much faster fire control[26]. **<u>RF6 was incorrectly being promoted as being a "*high performance firefighting agent*" implying "*as effective as AFFF*"[27] despite slgnificantly slower extinction times.</u>** Schaefer's own 2008 research[17] has also clearly shown this to be false, as has Jho's 2012[31,32] work and 2015 US Navy Research Lab testing[83].
Category: IPEN Section/ Page no.	**Claim?**	**CORRECTION**
5. C/S: Exec Summary p7, bullet	*"An unfortunate exception is US MIL Spec which, due to a legacy-wording technicality dating from the early 1960s requires the inclusion of fluorochemicals and has not been updated*	**<u>Misleading and incorrect</u>**. US MilF Spec 24385F was re-issued as MIL-PRF 24385F (SH) with amendment 2 on 7 Sept. 2017[28] to allow F3 agents to be considered. It requires the total fluorine content to be determined, and not exceed 800ppb (<1ppm) for PFOS or 800ppb <1ppm) for PFOA. **The**

2	*significantly since."*	**claimed IPEN definition on p22 that** "ANY CLAIM THAT A FOAM CONCENTRATE IS FLUORINE-FREE (F3) SHOULD BE SUBSTANTIATED WITH A TOTAL ORGANIC FLUORINE (TOF) ANALYSIS <10 PPM "F" AND IN ADDITION A TOTAL OXIDISABLE PRECURSOR (TOP) ASSAY." **10ppm equates to 10,000ppb Fluorine, which would ironically qualify ALL F3s as AFFFs.** A lot of F for something masquerading as F-free! It would also far exceed the maximum PFOS and PFOA requirements in this 2017 revised MILF Spec requirement[28]. **Confusing, as this suggests "fluorine free foams" by definition, do not have to be free of fluorine? Why not?** This latest US Mils Spec also states[28]: "***The DoD's goal is to acquire and use a non-fluorinated AFFF formulation or equivalent firefighting agent to meet the performance requirements for DoD critical firefighting needs***. ***The DoD is funding research to this end****, but a viable solution may not be found for several years. In the short term, the DoD intends to acquire and use AFFF with the lowest demonstrable concentrations of two particular PFAS, specifically PFOA and PFOS*." Were an F3 capable of passing this test there is little doubt it would be accepted. **BUT the reality is that no F3 agent is capable of meeting all the fire performance** (including when mixed with other qualified products), **or environmental performance, or dry powder compatibility components of this rigorous and thorough test**. All components are required to pass, along with compatibility testing with other qualified products, which F3s would fail due to viscosity issues. The passing of the **FAA Reauthorization Bill 2018** in October 2018[29] also provides US airports with the option of using ICAO Level C approved F3 agents from 2020 onwards, **but does not require it**. **Although ICAO Level C 's single freshwater only fire test should not be considered equivalent to MilF Spec's 7 separate fresh and saltwater fire tests including half-strength, over-rich, dry chemical compatibility and mixed with other qualified MilF Spec products – as any comparative assessment clearly reveals.**
2. SEH: Exec summary p 7, bullet 3	*"Fluorine-free firefighting foams have considerable financial, socio-economic, public health and environmental advantages over persistent fluorochemical based firefighting foams."*	**Misleading**. *Where is the evidence?* F3 foams are proven slower to control and extinguish volatile fuel fires[30], **increasing (not decreasing) smoke and life safety risks to communities and the extent of the whole incident. F3s lack of fuel shedding and inadequate vapour sealing**[31,32,83] **also**

		increase risks of slower extinction, unpredictable and sudden flashbacks and incident escalation which adds repair costs, business interruption, general community disruption and unnecessarily increased life safety risk (failing to deliver any financial or socio-economic advantages) compared to fluorinated agents. More F3 usage for longer is more likely to overflow containment areas and spill firewater runoff (including more foam with high BODs and potentially PFAS contaminants from the fire) into our environment[33,34]. Increased toxicity of these strong detergent F3s will kill more fish and aquatic life increasing (not decreasing) environmental harm, particularly when C6s are not categorised Bioaccumulative nor Toxic[10,11]. The UK Environment Agency concluded in 2014[35] ***"foam buyers primary concern should be which foam is the most effective at putting out the fire. All firewater runoff and all foams present a pollution hazard."*** **Evidenced by two environmental disasters where F3 was used – Fredericia Port in Denmark, 2016**[106,107] and the recent 30Aug 2018 **Footscray chemical factory fire in Melbourne Australia, which reportedly took 17 hours to gain "control" and over 5 days to completely extinguish**[3-5,36,37]**, using only PFAS-free foam** [3]**, …** all that time it was belching toxic smoke and firewater runoff into local rivers **including PFAS - detected 16x recreational water quality levels**[5]**, presumably as breakdown products of the fire**, killing hundreds of fish and other wildlife **exceeding 1,000kg**[4, 38]**, causing a local environmental disaster**! 55 million litres of contaminated runoff water had been pumped out[39] of the creek by day 3, into chemical waste facilities and WWTPs to try and reduce the adverse environmental impacts. It took until two weeks after the fire for PFOS levels in Stony Creek downstream of the fire site, to return back to recreational levels[126]. **This rose to approximately 70 million litres of water and 170 cubic metres of contaminated sediment removed from the creek by 24th Sept 2018**[141]. Victoria's chief environmental scientist Dr Andrea Hinwood said **the incident was "*probably as bad as it could be*" and the chemicals from the fire have had a "*massive*" impact on the system. "*We've had more than 2,000 fish killed*," she said**[142]. *See Appendix V para 4, p59 which contradicts this "reality" stating* ***"The poorer performance of F3 in this case can be overcome with a higher application rate."*** **By contrast, a major UK chemical fire was controlled in 2**

ED_002330_00159097-00014

		<u>hours and extinguished in 4 hrs using fluorinated AR-FFFP[99].</u> **<u>The UK Environment Agency also concluded in 2014[35] *"foam buyers primary concern should be which foam is the most effective at putting out the fire. All firewater runoff and all foams present a pollution hazard."*</u>** *See also p24, Myths 9, 1,2,& 3 below.*
8. C/R: Exec summary p 7, bullet 4	*"PFAS contamination often extends to agricultural land, waterways used for industry, recreation, fishing and aquaculture, as well as surface or groundwater used for drinking water."*	**<u>Misleading.</u>** **<u>This problem was caused by inadequately regulated intensive historic use of long-chain PFAS based foams for training, at specific training sites for decades, but not from any malice</u>**. Foam users were misled into thinking they were harmless for many years, particularly by a manufacturer ceasing global manufacture in 2002/3 confirming these products were not harmful[40]. It has become a legacy management issue of historic use and contamination, requiring remediation. **<u>Self-imposed</u>**[41,42] **<u>and regulatory management controls</u>**[43-45] **<u>over the last 20 years closely define containment, collection and use of firefighting foams by foam users,</u>** with increasing use of F3 or surrogate agents for training (where most foam is used). **This co-incides with a risk based approach to provide the high levels of life safety required**[46,104,140,146], while also minimizing the adverse environmental impacts of their use, whether fluorinated of fluorine free agents are being used.
8. C/R: Exec summary p 7, bullet 4 (pt 2)	*"Treatment to remove PFAS (especially short-chain PFAS) is very difficult and expensive with crops, fisheries, industries, livestock and human health values potentially exposed.*	**<u>Misleading and incorrect.</u>** It is not "very difficult" to remove short-chain PFAS.  Fig 2: OCRA process with airport fire training area in background. **Source**: Willson M, 2018 – "Cost-effective ≤C6 Remediation is Achievable", Presented at Ecoforum Australia, 2-4th Oct.2018. Several commercial scale technologies are available -**<u>like this 25,000L/day Ozone fractionative Reagent Addition (OCRA) separation system in use at an Australian Airport to treat firewater training runoff</u>** where PFAS is leaching from concrete, even when it rains[2]. It achieves PFAS

	Fluorine-free foams do not have this disadvantage."	**removal down to no detect levels (0.002µg/L sum PFAS)** to remove C4-C12 PFAS chemicals from AFFF contaminated firewater runoff, WWTP effluent, surface and groundwater[47-58]. **Also Misleading and incorrect**. **F3 - Fluorine free foams DO have this disadvantage** (unless it is a brand new training facility which has never seen PFAS usage or vehicles previously using PFAS at the site, or any valve seat, gasket or componentry containing PFAS materials). **Because PFAS derives from other breakdown products in most fires (particularly buildings, infrastructure and vehicle fires), even where only F3 is used**[3,5] *(eg. Footscray chemical fire – see Exec Summary bullet 3 above and Section 4 p34 below!).* PFAS remediation is required at Australian airport fire training areas which have been using F3 for the last 8 years[2], **because the concrete training pads are still saturated with PFAS (and estimated to be so for 25 years) which leaches every time they train with F3, use water only, even when it rains!** Irrespective of the foam type used, expect to have to collect, contain, and treat ALL firewater runoff from any training or firefighting incident as PFAS is likely to be present above the exceedingly low environmental acceptability criteria - from breakdown products of the fire, even if F3 is used – **proof is Footscray fire (*see Exec summary bullet 3 above*).** Queensland's 2016 Management of Foam Policy requires[59] *"Once foam is used, spilled or the concentrate requires disposal, the resulting fireter , wastewater or waste is dclased as regulated waste under environemntal regulations. This is due to them containing surfactants, and in many cases, persistent organohalogen compounds including all fluorinated organic compounds."*
8.C/R: Exec Summary p 7, bullet 5	*"PFAS pollution of sites resulting from foam incidents or training results in large, spreading down-gradient contamination plumes which may affect many kilometres off-site. Short chain PFAS (≤C6) are more mobile and more difficult to remove from ground- or waste-water than longer chain (>C6) compounds such as PFOS or PFOA."*	**Misleading.** Only true of historic sites occurring from intensive historical usage at specific training sites over many years in the same place, but management practices have changed dramatically, to prevent such events from occurring in future[41-46,104,140,146]. Such growing and spreading plumes have not been shown to occur from one-off isolated fire incidents. Changing to F3 use on such historic sites is unlikely to prevent leaching of PFOS/PFOA from concrete training areas, for up to 25 years after PFOS use ceased. Airservices Australia converted to F3 in 2010 and are still

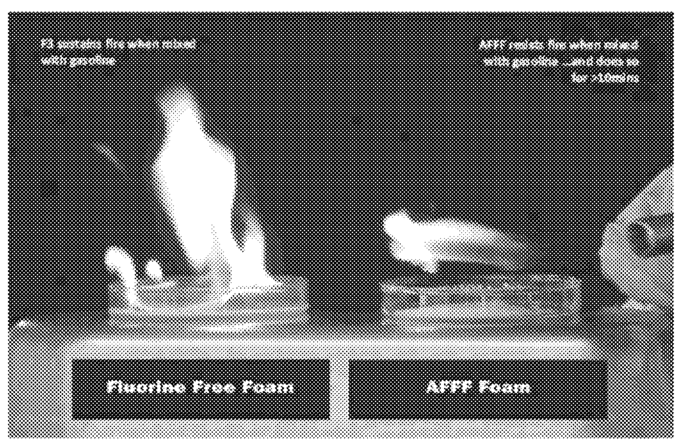
		leaching PFOS from training areas when F3 is used and even when it rains[2]. **C6 agents can be effectively removed commercially (*see Exec summary p7 bullet 4 pt 2 above*)**[47-58].
4. EI: Exec Summary p 7, bullet 6	*" … can cause limited, localised, short-term effects but will largely self-remediate. On the other hand, fluorinated foam releases have caused widespread, long-term pollution;…"*	**<u>Misleading.</u>** Larger volumes of F3 required for slower control of a given size incident, can lead to overflowing containment areas with noxious firewater runoff likely to contain higher levels of a 10 times more toxic F3 agent[16]. These larger volumes of high BOD liquids causing severe suffocation to all aquatic organisms and removal of fish from river systems for long (not short) periods[3,18]. Evidence from UK where heavy detergent foam loading prevented fish from re-colonising 2 major rivers following a major 1992 incident[64]. 6 years later 24,000 fish had to be returned to the river to re-set the ecological balance[65]. Footscray chemical fire in Melbourne is also a recent example[3-5,36-39] (*see Exec summary bullet 3 above*).
8. C/R: Exec Summary p7, bullet 7	*"PFAS contamination remediation and clean-up, if it is at all possible, is enormously expensive, time consuming with substantial socio-economic impacts such as loss of drinking water supplies, lost agricultural production, damage to river and offshore fisheries, depressed property values, economic and mental hardship for residents affected, as well as serious long-term public health consequences."*	**<u>Misleading</u>**. It is also likely to apply to any F3 usage in fire incidents as PFAS are likely to be fire breakdown products[3,5]. Evidence shows PFOS is detected from a fluorotelomer spill incident[33] and also leaches from concrete fire training areas even where F3 has 8 years usage for training[2]. This leaching occurs even when it rains. *See also Exec summary bullets 3 & 4pt 2 above.* *If it is such a "dreadful problem", why are regulators doing nothing to prevent the daily discharge from 95% of PFAS usage in PFAS laden effluent from WWTPs and landfill leachate around the world -UN Confirms only around 5% from firefighting foams*[1]*?* South Korea alone estimates 1,630kg of PFAS discharged in effluent each year[60]. Surely PFAS from foam usage is small by comparison?
1. OpE: Exec summary p7, bullet 8	*"…and demonstrated their effectiveness in operational use."*	**<u>Misleading</u>.** So why are there no details of fires effectively extinguished with F3 agents? … highlighting application rate, fire area, fuels, amount of F3 concentrate used, time taken to control and extinguish? Why did a planned 2016 Solberg F3 demo of ICAO level B fire test get substituted last minute by a C6 AFFF in 32°C humid Singaporean conditions[61]? Solberg explained because "***too many environmental factors were not under our control to do F3.***" Reportedly the same fire was unable to be extinguished twice using F3 the day before

		in 32°C conditions, and even caught the fuel separator alight indicating virtually no fire control.C6 AFFF provided progressive control and extinction without edge flickers, despite humid 32°C conditions. Are F3s suitable for such routine summer temperatures anywhere... or all year for tropical regions? Demos can be cancelled, real emergencies cannot[61]. Three weeks earlier a major Boeing 777 engine fire at Singapore, was extinguished in 2 mins using fluorinated AFFF/FFFP prior to safe evacuation of all 241 passengers and crew on-board [115,116]. **Reports of the <u>recent Footsrcay Chemical factory fire in Australia also suggest the reverse.</u>** It took over 17 hours to gain "control" and over 5 days to completely extinguish... all that time it was belching toxic smoke and firewater runoff into local rivers, killing over a tonne of fish and other wildlife! 55 million litres of contaminated runoff water had been pumped out of the creek by day 3, into chemical waste facilities and WWTPs[3-5,36-39]. *See also p4 para 3 above.*
Category: IPEN Section/ Page no.	**Claim?**	**CORRECTION**
2. SHE: Exec summary p7, bullet 10	*"A key advantage of fluorine-free foams is that they have almost none of the large and growing socio-economic or potential health impacts of fluorinated foam with only limited, short-term, localised environmental impacts which mostly self-remediate..."*	**<u>Misleading over-reach.</u>** Due to PFAS contamination in fire runoff from non-firefighting foam sources that will require F3 collection, containment, analysis and remediation treatment[3,5,,33,34,58,59]. *See also Exec summary bullets 3, 4pt 2, 8 & 12.*
8. C/R: Exec summary p8, bullet 11	*"Fluorine-free foams do not need complex, expensive and time-consuming remediation; if limited environmental damage occurs it is rapidly ameliorated, and very importantly, vital assets and amenities such as societal infrastructure, livelihoods, food supply, drinking water, public health, agriculture and livestock production, industrial continuity, recreational activities, etc., will*	**<u>Misleading and overly simplistic</u>.** **...They usually do when used in a fire incident or training ground where PFAS foam has been used historically** [2, 3,5,33,34,,58,59]. *See also exec summary bullets 3, 4 pt 2, 8 & 12 again.*

	rarely be under threat and if they are at all impacted will become normalised far faster with a minimal risk of long-lasting infrastructural, political and reputational damage."	
1. OpE: Exec summary, p8 bullet 12	*"Fluorine-free foams are available, certified and effective for all firefighting applications,.... As such there is absolutely no need for any exemptions, whether conditional, i.e., derogations, or otherwise,..."*	**Misleading and incorrect**. F3 agents may pass small scale indicative fire tests, but where is the large scale verification testing at similarly low applications rates which was done in the 1960s-1990s[21,66-70] proving the effectiveness of AFFFs and other fluorinated foams, underwriting the firefighting foam system design standards that followed. eg. NFPA 11. *Where is this evidence base for F3 agents that contradicts the tragedy of USS Forrestal[70-74]?* F3s do not seem to have undergone a similarly rigorous large volatile fuel fires testing program to confirm adequate acceptability for airports, military applications or MHFs (particularly large storage tank fires). Evidence of ICAO fire test dilution in 2013[12], poorer performance than fluorinated foams on Lastfire 11m tank testing with a non-representative 2 min pre-burn[75,76] raise significant questions about the adequacy at safely protecting lives of these F3 agents, when being used for larger scale fires, as the evidence seems lacking. In contrast an AR-AFFF extinguished a 82m dia US gasoline storage tank fire in 65 minutes, once the foam attack was set up and started[77] – 12 hours after the tank caught fire, 25 million litres of fuel was saved). Testimony in Washington State legislation exempted PFAS for continued MHF uses[24] (*see comments Intro p4 & Panel p5&6*). No substantial large volatile fuel fires demonstrated as quickly, effectively, reliably and successfully extinguished by F3 agents seem to have been publicly evidenced, in contrast with proven numerous successful AFFF fire performances[77-79, 115,116]. **A <u>disturbing Boeing 777 crash in Dubai 2016</u> at 48°C with very low relative humidity (8.4%),[114] <u>burnt for 16 hours</u> until the airframe was destroyed[61-63]. F3 is reportedly used by Dubai international Airport (see Appendix 1) strengthened by a final report still not issued, to explain reasons for this fundamental firefighting failure, over 2 years after the accident**. ***So was F3 used?*** *See also p4 para 3 above.*

1. OpE: Exec summary p8, bullet 13	*"The continued use of PFAS foams is not only unnecessary but would continue to add to the legacy and on-going contamination that is responsible for the substantial, widespread and growing socio-economic and environmental costs being experienced globally."*	**Misleading and incorrect.** **This assertion puts life safety at unnecessary extra risk, since F3s are not adequately proven on large volatile fuel fires and in-depth fuel fires**[75,76], including aviation fires [61-63, 115]. Yet fluorinated foams are proven highly effective. Current management controls on firefighting foam training, discharges and fire incidents (including those where F3 is used) would prevent such historic legacy issues being perpetuated[24,41-46,59,80]. Current remediation and removal technologies for PFAS are increasingly applicable to firewater runoff, whether fluorinated foam or F3 has been used to avoid unnecessary PFAS contamination[24,41-46,59,80]. Regulators should be preventing PFAS from 95% of other ubiquitous uses from being discharged daily from WWTPs and landfill leachate, year round, globally. South Korea estimates 1,630kg of PFAS is discharged from WWTPs every year[60]. This is a far more serious problem contributing to elevated environmental levels, than from short-chain C6 firefighting foams, which reduce socio-economic disruption and increase life safety by fast acting fire control and extinguishment, using least foam and water resources.
7. FoF: Sect. 1.2, p19	*"The first successful development of a true synthetic fluorine-free Class B foam was achieved by Ted Schaefer a formulation chemist working for the 3M Company, and named RF or 're-healing foam'.*	**Misleading and factually incorrect.** The first modern Class B F3 agent public launch and demonstration to foam users was of Angus Fire's Syndura at RAF Manston UK, on 12th June 2002[25]. It was launched with concerns over potential flashbacks and poorer vapour sealing ability than AFFFs. Later confirmed by Schaefer's own 2008 research[17] ***"…best F3 provides only 30% durability of AFFF on gasoline"***, supported by 2015 NRL research[82]**.** Subsequent comparative testing also showed Syndura performed as well if not slightly better than Solberg's RF6 F3 agent[26], which was incorrectly promoted by some as being "as effective as AFFF", when Schaefer's own 2008 research[17] showed this to be false. Subsequently confirmed by Jho's 2012 and NRL's 2015 research[31,32,82].
5. C/S: Sect. 1.3, p20	*"Modern generation Class B fluorine-free foams are capable of meeting the same high-performance standards as almost all AFFF-type foams."*	**Misleading.** Firstly, there is **no substantial evidence** supporting equivalent effectiveness of Fluorine Free Foam (F3) agents to AFFFs, particularly when **ICAO deliberately dilutes its Level B and Level C fire tests in 2014, to allow low quality AFFFs and F3s to pass, when previously they failed**[12]. Secondly, ICAO Certificates have been issued for F3 agents **certifying a PASS, when unacceptably low**

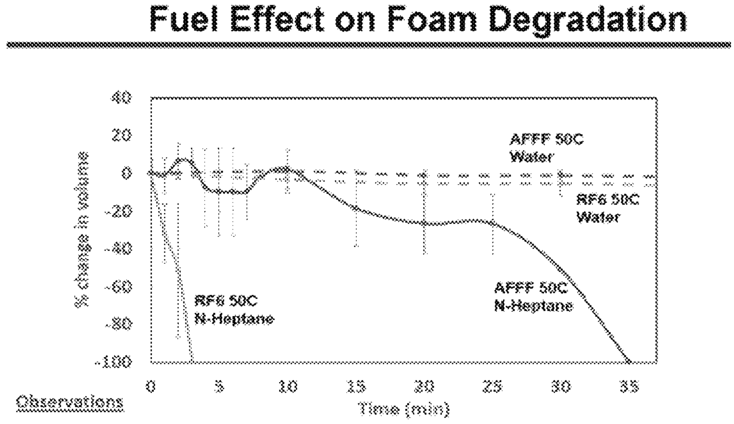
ED_002330_00159097-00020

		<u>ambient conditions of 0°C[13] were somehow "accepted"</u> as meeting the ≥15°C ambient testing requirement. This foam given a pass, actually FAILED the required criteria. Thirdly – *Why did a planned 2016 Solberg F3 demo of ICAO level B fire test get substituted last minute by a C6 AFFF[61] in 32°C humid Singaporean conditions?* Solberg explained because "***<u>too many environmental factors were not under our control to do F3</u>***." Reportedly the same fire was unable to be extinguished twice using F3 the day before in 32°C conditions, and even caught the fuel separator alight indicating virtually no fire control. C6 AFFF provided progressive control and extinction without edge flickers[61]. *Are F3s suitable for such routine summer temperatures anywhere... or all year for tropical regions?* Demos can be cancelled, real emergencies cannot. Further research by Jho in 2012[31] showed that **when F3 and AFFF foams are mixed with gasoline and exposed to an ignition source above the foam blanket, the fluorine free foam sustains ignition immediately**, while the AFFF resists ignition, even after 10 minutes. Comparison F3 v AFFF equally mixed with gasoline and placed in a petri dish. When a flame is introduced above the foam blanket, F3 immediately ignites and sustains ignition until it burns away, while AFFF resists ignition, ...and does so for more than 10 minutes.  *Source: Jho C, 2012 – You Tube Comparative video tests "Flammable firefighting foams - evidence superior burnback when AFFFs are used on volatile fuels like gasoline , www.youtube.com/watch?v=IuKRU-HudSU* *How can these F3s be considered the same?* Watch the video[32] <u>www.youtube.com/watch?v=IuKRU-HudSU</u>
5. C/S: Sect. 1.3, p20	*"Although the best F3 products on the market are able to match the performance of many MIL-Spec foams, they technically cannot achieve MILSpec approval by definition because they do not contain fluorine or have positive spreading coefficients necessary for film-formation, legacy out-of-date*	**<u>This is misleading and incorrect</u>**. The best F3s are not able to meet US MilF Spec 24385F "because they do not contain Fluorine", **was re-issued as MIL-PRF 24385F (SH) with amendment 2 on 7 Sept. 2017[28]** **<u>to specifically allow F3 agents to be considered</u>**. It requires total fluorine content of any foam used to be determined, and not exceed 800ppb (<1ppm) for PFOS or 800ppb <1ppm) for PFOA. It also states: "***<u>The DoD's goal is to acquire and use a</u>***

ED_002330_00159097-00021

	requirements of the specification [MIL-Spec or MIL-F-243385F]."	***non-fluorinated AFFF formulation*** ***or equivalent firefighting agent to meet the performance requirements for DoD critical firefighting needs. The DoD is funding research to this end****, but a viable solution may not be found for several years."* **Its short term aim uses minimum amounts of C6 PFAS chemicals in AFFF, driving PFOS and PFOA content towards zero**, while still meeting all other MilF Spec requirements. USAF spent $US 6.2m replacing legacy C8 foams with C6 AFFF in 2016[83]. Were an F3 capable of passing this test there is little doubt it would be accepted. **BUT the reality is that no F3 agent is capable of meeting all the fire performance** (including when mixed with other qualified products), **or environmental performance, or mixing with other agents, or dry powder compatibility components of this rigorous and thorough test** (otherwise it may be in use by now). From the assertion on p22 that "ANY CLAIM THAT A FOAM CONCENTRATE IS FLUORINE-FREE (F3) SHOULD BE SUBSTANTIATED WITH A TOTAL ORGANIC FLUORINE (TOF) ANALYSIS <10 PPM "F" AND IN ADDITION A TOTAL OXIDISABLE PRECURSOR (TOP) ASSAY." **10ppm (10,000ppb) is a lot of F for something masquerading as F-free!** This puts it clearly in an "acceptable" AFFF category, since it would far exceed the maximum 800ppb PFOS and 800ppb PFOA requirements in the 2017 revised MILF Spec requirement[28] and has a signifcant F content. *Confusing in itself, as this is suggesting a "fluorine free foam" by definition, does not have to be free of fluorine?* **Why not? ...otherwise it must be defined as an AFFF.**
5. C/S: Sect. 1.3, p20	*"NFPA 403* [latest 2018 version] *list fluorine-free foams (F3) as acceptable alternatives to AFFF, FP and FFFP for use in the Aviation Rescue and Firefighting (ARFF) at airports. As pointed out in NFPA 403, the need for extinguishing a fire can occur either immediately following an aircraft accident/incident, or at any time during rescue operations, and must be assumed at all times. The most important factors bearing on effective rescue in a survivable aircraft accident are the training received, the effectiveness of the equipment, and the speed with which personnel and equipment*	**Misleading.** NFPA 403:2018[84] lists F3 as acceptable. **NFPA 403 also accepts "equivalency" between ICAO Level C and MilF Spec., ...but without any justification.** A comparison of these 2 test protocols makes it abundantly clear **they are far from equivalent** in anything but a similar application rate and nozzle pressure. The ICAO UNI86 nozzle being a hand-made high performance nozzle, whereas MilF more closely resembles standard Military nozzles in field use. ICAO allows more than double the extinguishment time of MilF Spec at a similar application rate – *Why?* **MilF Spec also requires 7 fire tests for acceptance** (ICAO requires just 1, using freshwater only) **including ½ strength and over-rich fire tests in both fresh and seawater, demanding fast extinction (55 seconds for the lowest application rate, compared to 120secs for ICAO Level C), plus environmental performance, dry chemical compatibility and corrosion testing (not required by ICAO Level C) which F3s probably would not pass.** *Why*

	designated for rescue and firefighting purposes can be put to use."	*does NFPA 403;2018[84] surprisingly extends its Airport Rescue and Fire Fighting (ARFF) response time by 50% from 2mins to 3 mins in the latest 2018 version?...* again **without any clear justification or evident passenger benefit …This does not seem to relate to the survivable atmosphere inside the aircraft which historically has been considered to be around 3 mins –allowing up to 2 mins to respond and get there, up to 1 minute to apply foam, extinguish the fire and start safely evacuating passengers.** *Have fuselage survivable atmospheres shot up from typically 3 mins to over 5 mins? If so, …where is the evidence?* It is misleading and confusing to suggest the most important factor - speed with which ARFF equipment (including foam) can be put to use, **is compromised WITHOUT impacting passenger safety.** *Why does NFPA 403:2018 delay response times by 60 secs, and endorse further 60 sec delays in ICAO Level B and C fire tests[12] since 2014 changes?* **A double whammy delay, allowing poor quality AFFFs and F3 to pass (when they previously failed) and jeopardizing passengers, crew and firefighters safety.** Easier Kerosene fuel (flashpoint 37-55°C) was also permitted from the previous insistence of Jet A1 (FP 38°C), which is used by most commercial jet aircraft. *Why these changes …if not to make the test easier for F3 to pass?* **Clearly ICAO Level C has NO "equivalency" to MilF Spec.**
9. Oth: Sect. 1.3, p20	*"There is currently considerable resistance from vested interests and lobbying groups representing the US chemical industry to these changes, with many unfounded or untrue assertions and myths, downplaying the effectiveness and operational efficiency or safety of fluorine-free foams (F3)."*	**This is false and misleading.** Foam and fluorochemical manufacturers are primarily interested in **ensuring good fire protection is being provided to protect life safety, property and the environment**[41,42,46]. In many cases over the last 50 years fluorinated foams have achieved these objectives more effectively and efficiently than any potentially alternative non-fluorinated agents. **There is widely available sound scientific evidence and extensive fire testing data on which to caution potential foam users about the potential drawbacks of F3 foams**[17,18,22-24,27,30-32, 35,36,46,61-63,64-74,77-79,82,83,85-87 0-32,86-89], particularly for MHFs where larger fires involving volatile fuels, forceful application, high ambient temperatures and **where people's lives may be put at increased risk** (including firefighters and other emergency responders), by the inappropriate use of F3 agents. US Naval Research Labs **found F3 significantly degraded by unignited gasoline** at room temperature. F3 lasting only 3 mins, compared to 35 mins for AFFF[32].

		 **Source:** Hinnant K et al, 2015 -Evaluating the difference in foam degradation between Fluorinated and fluorine-free foams for improved pool fire suppression, US NRL, Exchange meeting Aberdeen proving ground, MD.
5. C/S: Sect. 1.3, p20	*"Many fluorine-free F3 products on the market are capable of meeting the following performance specifications as do the better AFFF formulations:* *• EN1568:2008 Parts 3 and 4 all fuels, fresh and saltwater, polar solvents (acetone and isopropanol, IPA) some quote 1A/1A; caution may be required as there is some indication that a 1A result on polar solvents points to siloxane surfactants being used which may have potential environmental persistence problems of their own depending on structure;* *• ICAO Level B and Level C at 3% and 6% (Aviation);* *• LASTFIRE batch approvals on both heptane and ethanol, fresh and saltwater;* *• IMO – MSC.1/Circ.13.12. (International Maritime Organisation);* *• UL162 with fresh and seawater;* *• UL162 listed Type III and sprinklers on hydrocarbon fuels;* *• FM 5130 approved;* *• ULC 5564."*	**<u>This is very misleading. It incorrectly implies equivalency</u>.** *It also seems to suggest that meeting the requirements of these small scale tests is somehow an end in itself? ...Where are the large scale verification tests (up to $3000m^2$) which took place to verify AFFF large fire performance before the standards (eg. NFPA 11) were written?* **<u>These fire tests are only ever intended to be informative indications of how a foam may perform in a real fire related to that application</u>**[12,89] with a built in safety factor, but are usually conducted in favourable conditions. *Should they now be considered an end in themselves?* We also see ICAO diluting that safety factor and allowing previously inferior products to PASS. **Just because an F3 agent or AFFF may pass a small test <u>under potentially ideal or managed conditions</u>** (*perhaps only once out of 10 or more attempts?*) to gain a flimsy piece of paper**<u>, does not automatically mean it is well suited to any possible real emergency application related to that fire test protocol</u>.** **It is well known that <u>some manufacturers are always seeking the easiest combination of factors that would allow a specific foam to pass a specific test</u>[13] <u>– searching for "ideal conditions"</u>.** Some examples follow: Tests like **ICAO**, allow testing at ≥ 15°C – hardly representative of summer conditions in most places, or year round in the tropics, *yet I have an ICAO approval certificate[13] for an F3 agent at 0°C ambient and fuel temp 5°C, which fails the test criteria, so why was it issued?* Perhaps this helps explain *why did a planned 2016 Solberg F3 demo of ICAO level B fire test get substituted last minute by a C6 AFFF in 32°C humid Singaporean conditions[61]?* As Solberg explained because ***<u>"too many environmental factors were not under our</u>***

control to do F3." (ie. The conditions were not ideal enough to allow us to get F3 to work on the day in that heat), so the safety margin supposedly built into these fire safety standards had **already been eroded, to a point where F3 was unable to even deliver effective control of the fire**[12], never mind provide any extinction. Yet a C6 AFFF did this effortlessly and effectively! Hardly evidence of equivalency? *Why the dramatic difference if they both pass the same ICAO Level B test and are certificated?* Three weeks earlier a major Boeing 777 engine fire at Singapore, was extinguished in 2 mins using fluorinated AFFF/FFFP prior to safe evacuation of all 241 passengers and crew onboard[115,116].

The **dilution of ICAO Level B and C fire tests in 2014 has done nothing to improve or enhance this fire safety standard, for anyone**[12]. The reverse may be true - it may have created insufficient safety margin to allow approved foams to control fires under more extreme conditions, as possibly evidenced in 2016, by the **failed Singapore demo and Dubai Boeing 777 aircrash disaste**r[61-63] (*see Exec summary bullets 3, 4pt 2, 8 & 12*).

EN1568 is a confusing standard because it was designed to allow all European varying quality foams to pass somewhere in its complex rating spectrum. Claiming a foam passes EN1568 parts 3 & 4 alone is meaningless – because they all do, or should - at some level. **Few foam users realise that it is only a 1A/1A pass or a 2A/2A pass at EN1568 Part 3**[88] **on hydrocarbons in fresh/seawater testing, that confirms forceful application suitability**, of that product onto hydrocarbon fuels. All other passes including 1B/1B through to 3D/3D are only approved for gentle application of the product, not forceful application where it has already been shown during testing to be incapable of achieving that forceful requirement. Of very few can achieve a 1A/1A hydrocarbon fuel rating (at least one believed to be without Siloxanes!), **so by far the majority of F3 agents do not equate to AFFF fire performance**, as virtually all reasonable AFFF agents (including AR-AFFFs, FFFPs and AR-FFFPs) can achieve a 1A/1A EN rating. Most Fluoroprotein (FP) agents (without film forming additives but containing smaller amounts of fluorochemicals) pass at 2A/2A which is a slightly slower, but still forceful application pass capability. For polar solvents (EN1568-4: 2008[117]) there is no pass category for forceful application. **All foams whether fluorinated or fluorine free are recommended for gentle application (confusingly even 1A/1A is achieved through a gentle backboard fire test) to polar solvent fuels**[117], to minimise

		mixing with fuel (as all polar solvent fuels are destructive of all foams forcefully applied– whatever type, to a greater or lesser extent). **It therefore qualifies gentle application only on polar solvents**. This is certainly not made clear in this document. **Lastfire** is not an "approval" or fire test "standard", as is misleadingly implied here. It is simply a **batch conformity test protocol only**[118] to indicate suitability of a specific foam batch to storage tank fire applications. In reality any agent with significant water soluble polymer levels is likely to pass… it is a much tougher test of any foam without polymer additives, like FP foams and standard AFFFs, No fluorine free synthetic foam without polymers would be expected to pass this test. **IMO** is perhaps the least demanding of these fire tests, so virtually any reasonable Class B foam, whether fluorinated or fluorine free should pass. **UL 162**[89] is a benchmark test set at a fixed bar. **There is no recognition for a foam that does very well, against one that just scrapes over that bar**. It covers a range of tests to ensure a proprietary foam system will work effectively, so no foam agent alone can be approved. Any foam is only approved with an approved proportioning device and foam delivery device. The foam quality fire tested must be representative of the foam delivery device. Interestingly **comparative UL 162 fire testing in Sweden (2016)[85] confirmed that a C6 AFFF was able to gain approval with a wider range of expansion ratios and lower application rates** representing different delivery equipment than an F3 agent which only passed at 7.5:1 expansion (failing the burnback test at 4.4:1 expansion), but **both F3 tests using higher 11.4L/min application rates.** C6 AFFF passed at 3.6:1 and 6.9:1 both at the lower 7.6L/min application rate without problems, verifying clearly increased superiority and flexibility of C6 AFFF. **F3 only passes the UL sprinkler test by a quirk of the fire test**, requiring the lowest and furthest nozzle pressure (usually 7psi) to be used[89]. Hence there is little plunging force to mix the F3 agent in with the fuel, delivering essentially quite gentle application. It is therefore likely at higher operating pressures the agent will be less effective on the fire, as foam is delivered far more forcefully into the fuel surface, where normally only fuel shedding and vapour sealing AFFF agents are proven to be most effective. Anyone considering F3 for non-aspirated or sprinkler applications, should first ensure the preferred

		agent is fire tested in a forceful plunging action into the fuel being protected at a realistic system pressure. If it fails or is very slow to extinguish, a fluorinated alternative should be tested as a comparison, and considered for use. **Many tests can be set up to exploit optimal conditions, so they are easier to pass[12,13], so foam buyers need to BEWARE, understand the limitations of approval testing, and ensure any foam is adequately and robustly tested using the regular equipment and fuels being used on site in the worst prevailing ambient conditions (usually maximum summer temperatures) to verify acceptability - BEFORE purchase.** This IPEN paper even seems to contradict itself …in sect 1.3, p 21 ***"These approvals and certifications remain just that, somewhat artificial hurdles that manufacturers have to jump through before being able to sell their products on the market*. In exercising due diligence during the procurement process end-users must do their own operational fire performance testing under the conditions they would normally operate in regardless of foam type (for example, ambient temperature or humidity), with the equipment they would normally use such as inductors, hose and branch nozzles, and with the test being carried out by their own firefighters.** *It should also be acknowledged that operational technique and training are vital in achieving the top performance from any product." And p22…"* ***The key to the applicability of any small-scale test is its validation against real events and realistic large-scale testing representing real world design scenarios****." This is correct, but where is the large scale testing representing real=world scenarios with F3s? Its been done in the past for AFFFs and fluorinated foams[21,66-74]. You can't have it both ways…*
Category: IPEN Section/ Page no.	**Claim?**	**CORRECTION**
7. FoF: Sect. 1.3, p22	ANY CLAIM THAT A FOAM CONCENTRATE IS FLUORINE-FREE (F3) SHOULD BE SUBSTANTIATED WITHA TOTAL ORGANIC FLUORINE (TOF) ANALYSIS <10 PPM "F" AND IN ADDITION A TOTAL OXIDISABLE PRECURSOR (TOP) ASSAY.	**Incorrect.** *Surely any Fluorine Free Foam should be what it says – FREE of FLUORINE both in organic and inorganic form?* **…10ppm is a lot of F for something masquerading as F-free!** This makes it **acceptable as an AFFF**, since it would far exceed the maximum PFOS and PFOA requirements in the 2017 revised MILF Spec[28] (≤800ppb PFOS and ≤800ppb PFOA. It also exceeds the 25ppb PFOA and

	MOREOVER, A TOP ASSAY IS ALSO ESSENTIAL FOR ANY MODERN 'PURE C6' AFFF CONCENTRATE CLAIMING TO BE LONG-CHAIN PFAS AND PFOA-FREE AT <1 PPM PFOA OR PRECURSORS.	1,000ppb of PFOA related substances permitted in EU REACH legislation 2017/1000 (June 2017) for short chain C6 flurosurfactants from 2020. *How can anyone expect any "fluorine free foam" by definition, to have levels of F acceptable in AFFFs? Why?...*so it can perform better perhaps? **It makes no sense!**
9. Oth: Sect.1.4, p22	*"Myth busting, truths, untruths and marketing hype section with "reality" positions."*	**Misleading, largely incorrect, disturbing rejection of scientific evidence.** **A bizarre "reversalism" of headings, where virtually all supposed "Myths" are factually correct with many claimed "Reality" positions, false.** *Why? They need to be ACCURATELY addressed and CORRECTED individually below:*
1. OpE: Sect. 1.4, p22 "Myth 1".	*"**Myth**: Fluorine-free foam endangers life safety for both fire fighters and members of the public.* ***Reality**: There is absolutely no evidence, anecdotal or otherwise, for this statement."*	**Misleading and factually incorrect.** **Evidence comes from significant scientific research and fire testing data well known to the authors**[17,18,22-24,27,30-32, 35,36,46,61-63,64-74,77-79,82,83,85-87] and the effects have been personally witnessed many times by the author of this response document, as irrefutable. **Lives can be placed at risk by any fire that continues to burn, increases intensity and escalates.** Any foam which rapidly controls and extinguishes that fire, effectively, efficiently and reliably, **preventing fuel vapour releases and without sudden flashbacks or re-involvement is protecting life safety.** Any foam which does not achieve these critical goals is necessarily placing that life safety at increased and unnecessary danger. **Fluorocarbon surfactants have been proven to substantially improve vapour sealing and reduce fuel pick-up in AFFFs to the extent that they will not burn when a flame is passed close to the foam blanket after vigorous mixing with flammable fuels like gasoline**[31,32]. The same fuel mixing with a foam without any fluorocarbon surfactants, immediately sustains ignition when a flame is passed close to the foam blanket, because vapours are not sealed off, fuel is also trapped inside each bubble, so vapour is being released between bubbles and as bubbles begin to collapse which can ignite from incandescent materials or naked flames nearby. The foam frequently continues burning until the fire is back to full intensity, which may take just 60 seconds or less on a smaller fire area. **This places any lives nearby at increased risk of harm**. Jho in 2012 clearly demonstrated this problem[31,32], **when F3 and AFFF foams are mixed with gasoline and exposed to an ignition source above the foam blanket, the fluorine free foam sustains**

ignition immediately, while the AFFF resists ignition, even after 10 minutes. *How can these F3s be considered equivalent?*
Watch this video of the tests
www.youtube.com/watch?v=IuKRU-HudSU

Jho's research went on to add small amounts of fluorochemical to the F3 foam repeating the test until the F3 ceased to sustain ignition… it had become an AFFF simply by the addition of critical vapour sealing and fuel shedding fluorochemicals, which improved its fire performance. It was also confirmed by US Naval Research Labs in 2015[82].

Independently witnessed ICAO Level B fire test results, Denmark 2012, compared to those results assessed against today's ICAO Level B test criteria (post 2014 ICAO update).

Table 17: Results From Fire Tests To ICAO Level B (2012)

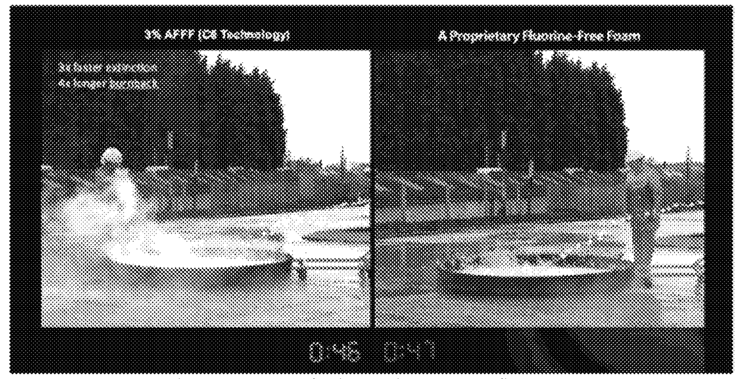
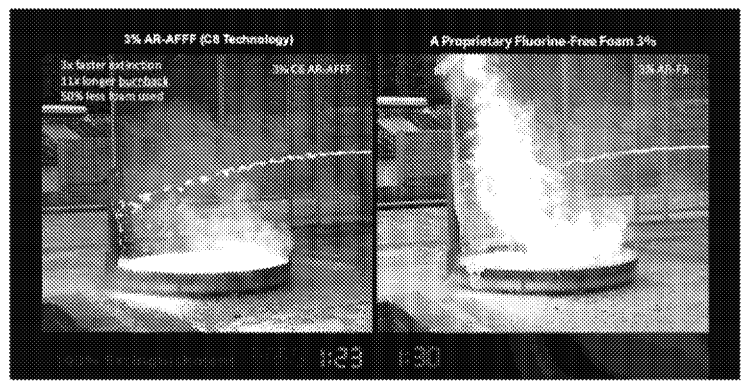
Test No.	Nozzle	90% CONTROL	99% CONTROL	EXTINCTION	25% BURNBACK	PASS/FAIL	NOW under 2014 ICAO Level B (Jet A1) Criteria	NOW under 2014 ICAO Level B + Kerosene?
SOLBERG - RF6								
3	UNI86	0' 35"	0' 45"	None	N/A	FAIL	FAIL	PASS
4	MMS	0' 30"	0' 45"	1' 58"	(6' 45")	FAIL	PASS	PASS
DR. STHAMER - Moussol FF 3/6								
9	UNI86	0' 40"	0' 45"	1' 24"	(7' 50")	FAIL	PASS	PASS
10	MMS	0' 35"	0' 55"	None	N/A	FAIL	FAIL	PASS
SOLBERG - RF3								
35	UNI86	0' 50"	1' 05"	2' 00"	(8' 30")	FAIL	PASS	PASS
36	MMS	0' 50"	1' 45"	None	N/A	FAIL	FAIL	PASS
FOMTEC - Enviro 3x3 Plus								
38	UNI86	0' 55"	1' 05"	1' 40"	(9' 50")	FAIL	PASS	PASS
BIOEX - Ecopol								
37	UNI86	0' 40"	0' 55"	1' 50"	(8' 05")	FAIL	PASS	PASS

MMS (Modified Military Specification); FXR (Foam Expansion Ratio); QDT (Quarter Drainage Time); CT (Control Time); EXT (Extinguishment Time); BB (Burnback Time).

Source: *Resource Protection International, 2012 - Fluorine Free Foam (F3) fire tests, Falck Nuberg training Centre, Esbjerg, Denmark Report P-1177. With additions reflecting current ICAO Level B acceptance criteria (since 2014 changes) some would now PASS.*

Extensive testing in Denmark 2012 showed **ALL F3 agents tested failed the ICAO Level B fire test** with a 60 sec extinction requirement[87]. **After dilution of the fire test in 2014 allowing 120sec extinction, most of these foam would now pass ICAO level B**… possibly all of them if the fuel was also changed from Jet A1 to Kerosene. *How can this be in the interests of improving public safety?* It seems to be putting lives in danger by allowing poor quality AFFFs and F3s previously failing to now pass this fire test. *Why?*

This second video[30] shows this combined problem delivering slower fire control/extinction (which maintains danger to life safety for longer) and poor resistance to re-ignition, by comparing F3s with AFFFs on the same fire test www.youtube.com/watch?v=3MG2fogNfdQ.

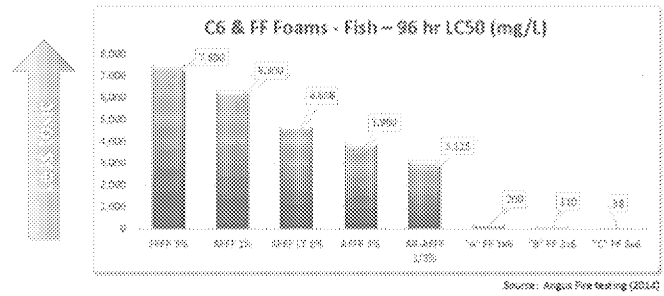
		Comparison ICAO Level B Jet A1 Fire Test : 3% C6 AFFF v 3% F3 (without Fluorine)  *Source: Angus Fire, 2013 – You Tube Comparative video tests "AFFF/AR-AFFF v Fluorine Free Foam (F3)", on ICAO Level B and EN1568-4 tests - evidence faster extinction, superior burnbacks and less agent usage with short-chain C6 fluorosurfactants,* [illegible] Comparison EN1568 - 4 Polar Solvent Fire Test : 3% C6 AR-AFFF v 3% AR-F3 (without Fluorine)  *Source: Angus Fire, 2013 – You Tube Comparative video tests "AFFF/AR-AFFF v Fluorine Free Foam (F3)", on ICAO Level B and EN1568-4 tests - evidence faster extinction, superior burnbacks and less agent usage with short-chain C6 fluorosurfactants,* [illegible] **<u>Life safety is placed at increased danger of re-ignition and escalation at any time, even when the fire seems out.</u>** **<u>F3 cannot be relied upon to prevent sudden and unpredictable re-ignition and re-involvement of the fire, which places life safety at unnecessarily increased danger</u>**. Ted Schaefer an author of this IPEN report even confirmed in his own 2008 F3 research[17] that ***"Under laboratory conditions, with a foam blanket 1-2 cm deep, best-performing FfreeF <u>formulation (RF6) provides about 30% of the durability of an AFFF</u> for protection against evaporation of low-flashpoint flammable liquids. We also note in the results the significant differences among FfreeF with <u>almost no sealability of AVGAS vapours offered by the two other formulations</u>."*** Supported by US Naval Research Laboratory in 2015[82] **<u>This evidence confirms Myth 1 is correct.</u>**
4. EI: Sect. 1.4, p22	*"**Myth:** Fluorine-free foams are ten times more toxic, based on acute aquatic toxicity, than AFFFs."*	**<u>Misleading and incorrect</u>.** This sounds like a "dilution of pollution is no solution" moment. **Just because 2 foams may inhabit a broad "relatively harmless" category compared to other highly toxic contaminants, <u>toxicity differences matter to fish,</u>**

ED_002330_00159097-00030

"Myth 2"

Reality: *Irrelevant hyperbole and misuse of data. ALL foams fall into the very low acute toxicity categories…Effectively ten times almost nothing is still almost nothing. …The real issue is the chronic long-term toxicity associated with permanent PFAS pollution by AFFF."*

aquatic organisms and ecosystem health[16].



Independent aquatic toxicity data comparison of C6 fluorotelomer foam agents with Fluorine Free (FF) foams from French Eurofins Toxlab Report (presented 2016 Singapore conference)

Aquatic toxicity data confirms Class B F3 agents are between 10 and 30 times more aquatically toxic than AFFFs, which means life or death, if you are a fish.

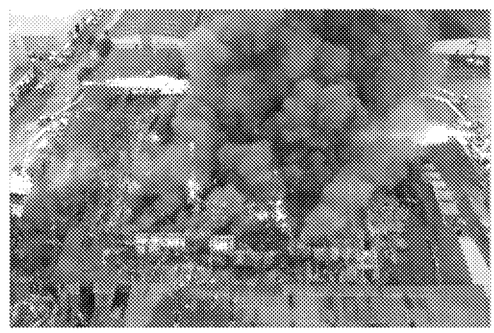
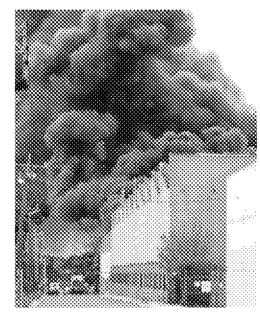
Testing of Rainbow Trout, a sensitive species to pollutants in European rivers, shows **that 50% of the test fish die over a 96 hr period when just 65µg/L of F3 agent is present** in the water. Increase that level by a higher volume of F3 contaminant and more fish die. Testing using AFFF showed **50% of the test fish only died when 30 times more AFFF was added** to the water (ie. 2,176µg/L)[90].

Table 1 - 96-hour LC50 Test in Fingerling Rainbow Trout

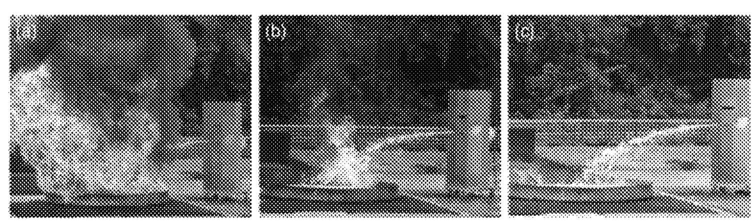
Agent	LC50 (mg/L)
Wetting Agent	1.06
Fluorine-free Foam A	65
Fluorine-free Foam B	71
Milspec AFFF	2176
AR-AFFF	3536
UL AFFF	5657

This becomes particularly significant in fire incidents when typically 2-3 times higher usage of F3 agent is likely to be required in a real fire incident, compared to the more effective AFFF. *See also Myth 1 above.* Containment areas for firewater runoff are more likely to overflow when higher volumes of foam and water resources are used. **More F3 usage means higher aquatic toxicity and BOD levels in the runoff which may overflow into a river**[18]. **Result: Substantially more fish die than if less volume of a less toxic AFFF was used, with a lower risk of an overflow occurring**[16,18,90].

		In addition, BOD levels litre for litre of F3 and AFFF are similar, and on average F3 is often slightly less than AFFF (maybe 10-15%)[91]. However this is **more than overwhelmed when 2-3 times more F3 agent is used in an incident than AFFF, and has a greater risk of overflowing containment areas**[17,18, 30,82]. Larger volumes overflowing dramatically increase the oxygen depleting ability of the foam entering the river[3-5]. **Less foam entering = less oxygen depletion. PFAS chemicals are not very** toxic[6,92-96]. **Detergents (hydrocarbon surfactants) are the most toxic of all foam ingredients**[97] **and F3 agents boost detergent levels to try and offset lack of fluorochemicals to boost foaming capability. Chronic long-term toxicity is not particularly associated with PFAS chemicals**, it is their persistence over time which is the greater concern particularly with legacy C8 PFAS which are also bioaccumulative and toxic[43,44]. **Environmentally more benign C6 short-chain PFAS chemicals are categorized as NOT bioaccumulative and NOT Toxic**[11], so they have a far less disruptive long-term effect on the environment than legacy long-chain PFAS. C6 are supported by the US EPA PFOA Stewardship Program[41] under which all fluorochemical manufacturers voluntarily transitioned away from C8s to more benign C6 PFAS between 2010 and 2015. **C6 short-chain PFAS chemicals meet the stringent PFOA restriction legislation passed by European Union (EU REACH legislation 2017/1000 – June 2017)**[45]. All leading foam manufacturers have also transitioned their foam formulations to use only high purity C6 PFAS ingredients since 2016[98]. **This evidence confirms Myth 2 is correct.**
1. OpE: Sec. 1.4, p22 "Myth 3"	*"**Myth**: Up to three to four times more fluorine-free foam is required compared to a fluorinated foam."* ***Reality:** False – examination of the single incident behind this claim finds that the concentrate application rates were almost identical."*	**This is misquoted, misleading and incorrect.** …Normally 2-3 times more F3 is required on large volatile fuel fires, and the evidence does not relate to a single incident[61-63,71-74,79,36,37,116]. **Ted Schaefer's own 2008 F3 research**[17,82] **confirms *"Under laboratory conditions, with a foam blanket 1-2 cm deep, best-performing FfreeF formulation (RF6) provides about 30% of the durability of an AFFF for protection against evaporation of low-flashpoint flammable liquids."*** F3 collapses 3 times faster on heptane/Avgas spills than AFFF, using 3 times more F3. **UL 162 has different category for F3's requiring a higher**

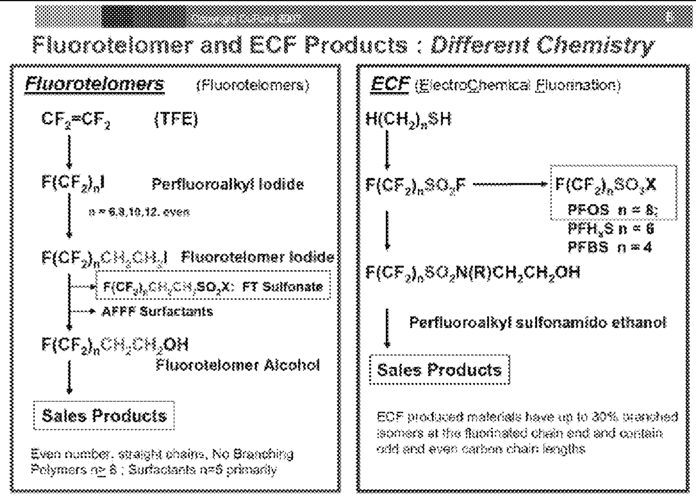
		application rate[89]**,** **<u>nearly 3x more foam to extinguish and few listings.</u>** UL 162 needed 3x more F3 to extinguish at 7.5:1. but same F3 failed at 4.4:1, compared to C6 AFFF passed at both similar expansions with 1/3rd the foam quantity. Also evidenced by the recent 30Aug 2018 **Footscray chemical factory fire in Melbourne Australia, which reportedly took 17 hours to gain control**[36] **and around 6 days to completely extinguish,**[37] **only used PFAS free foam agents**[3]**, ...** all that time it was belching toxic smoke and excessive firewater runoff into the local river - including 16 times recreational water levels of PFAS detected from EPA sampling data[5], presumably as breakdown products of the fire, killing over a tonne of fish and other wildlife **causing a local environmental disaster**[4]!   Footscray Chemical Fire, Melbourne, VIC – 31Aug2018 55 million litres of contaminated runoff water had been pumped out of the creek by 3rd day[38], into chemical waste facilities and WWTPs. **<u>This rose to approximately 70 million litres of water and 170 cubic metres of contaminated sediment removed from the creek by 24th Sept 2018</u>**[141]. Victoria's chief environmental scientist Dr Andrea Hinwood said **<u>the incident was "*probably as bad as it could be*" and the chemicals from the fire have had a "*massive*" impact on the system. "*We've had more than 2,000 fish killed,*" she said</u>**[142]. *<u>See Appendix V para 4, p59 which contradicts this "reality" stating</u>* ***<u>"The poorer performance of F3 in this case can be overcome with a higher application rate."</u>*** **<u>By contrast, a major UK chemical fire was controlled in 2 hours and extinguished in 4 hrs using fluorinated AR-FFFP</u>**[99]**.** **<u>The UK Environment Agency also concluded in 2014</u>**[35] ***<u>"foam buyers primary concern should be which foam is</u>***

ED_002330_00159097-00033

		<u>the most effective at putting out the fire. All firewater runoff and all foams present a pollution hazard.</u>" **<u>This evidence confirms Myth 3 is correct.</u>**
Category: **IPEN Section/ Page no.**	**Claim?**	**CORRECTION**
3. FP: Sect. 1.4, p22 "Myth 4"	*"**Myth:** Fluorine-free foams do not work at higher-than-normal ambient temperatures on hot fuel.* ***Reality:** A leading brand of fluorine-free foam has been shown to work at elevated temperatures, with very high vapour pressure fuels at both high fuel and ambient temperature (28-29°C as well as 36°C) - most importantly the test application rates were significantly lower than the minimum use rates allowed by industry."*	**<u>Misleading</u>.** No-one is suggesting F3s do not work at "**higher** than normal ambient temperatures" (although that is also probably the case). **It is proven they sometimes do not even work at <u>normal</u> ambient temperatures for summer around most of the world... ie ≥32°C[61-63].** *Why did a planned 2016 Solberg F3 demo of ICAO level B fire test get substituted last minute by a C6 AFFF in 32°C humid Singaporean conditions[61]?* Solberg explained because "***<u>too many environmental factors were not under our control to do F3.</u>***" Reportedly the same fire was **unable to be extinguished twice using F3 the day before in 32°C conditions, and even caught the fuel separator alight indicating virtually no fire control**.C6 AFFF provided progressive control and extinction without edge flickers, despite humid 32°C conditions.  ICAO Level B Fire test demo in Singapore, 2016. (a) pre-burn; (b) ≤C6 AFFF fire control; (c) ICAO Level B ≤C6 AFFF extinguishment Demos can be cancelled, real emergencies cannot. Three weeks earlier **a major Boeing 777 engine fire at Singapore, <u>was extinguished in 2 mins using fluorinated</u> AFFF/FFFP prior to safe evacuation of all 241 passengers and crew onboard**[115, 116]. **<u>A disturbing Boeing 777 crash in Dubai 2016 at 48°C, burnt for 16 hours until the airframe was destroyed</u>[61-63].**

		 Dubai B777 fire burned for 16 hours. **IPEN's Appendix 1 confirms Dubai International Airport as a major F3 user, apparently since 2011[127], with recent fire truck F3 samples passing routine laboratory testing, strongly suggesting it was used in this Aug2016 B777 crash**. *Why is the final investigation report still not issued to explain this firefighting failure - over 2 years later?* A single F3 brand may be able to operate at "elevated" 29°C temperatures under certain test conditions – *maybe this contained 10ppm Fluorine?* **This does not seem to represent most F3s, and the evidence presented does not translate to fast, effective and reliable fire control and extinguishment under elevated emergency fire conditions[78,115,116]**. *Where is evidence of F3 major firefighting capability or reliability on large volatile fuel fires, in the public domain?* ***'The problem with remote yet potentially catastrophic risks - they do sometimes materialise, then otherwise very reasonable decisions start to look very UNreasonable, …even criminal'*** **On the evidence presented it seems that Myth 4 is probably correct.**
3. FP: Sect. 1.4, p22 "Myth 5"	***Myth:*** *Fluorine-free foams cannot be used for vapour suppression of chemically reactive liquids/vapours such as ammonia.* ***Reality:*** *A commercially available fluorine-free foam applied using CAFS technology as a low expansion foam is capable of providing efficient ammonia suppression when compared to other AFFF products on the market with negligible loss of ammonia from the aqueous sub-phase."*	**Misleading.** It is possible F3s could be effective at vapour suppression of Ammonia when aided by CAFS (Compressed air Foam System) technology (as AR-AFFFs could similarly benefit), but **when compared unaided by CAFS,** F3 may be less effective than unaided AR-AFFF in this regard. Lastfire testing (Oct. 2017) confirmed "*CAFS was shown to be much more forgiving of foam quality*"[75,76] effectively levelling fire performance between F3 and C6 AFFFs. However, it is likely to be difficult to deploy sufficient CAFS equipment and compressors to facilitate effective CAFS delivery for large ammonia spills (or other major fires) in any emergency. **On the evidence presented it seems that Myth 5 is probably correct.**

3. FP: Sect. 1.4, p23 "Myth 6"	*"**Myth:** Modern purer C6 fluorotelomer based foams are direct drop-in replacements for the older generation C6/C8 fluorotelomer foams.* ***Reality:** C6 are not absolute "drop-in" replacements. …currently there are no known approvals available for the newer C6 products to be used for sub-surface injection on large storage tanks."*	<u>**Misleading and factually incorrect**</u>. **Leading C6 fluorotelomer based foams have been demonstrated to be drop-in replacements for older generation C6/C8 foams. Some** leading high purity C6 agents have contained 95-97% ≤C6 content since 1981, a few even 50% C6 since 1970's[100]. Comparative testing between 3M C8 MilF spec approved foam agents and **high purity C6 agents showed the C6 agents were able to pass all MilF Spec tests with 40% lower Fluorine content than the 3M C8 product**[100], back in 1981. Ansul Mil-spec (AFC-5&5A)(1981)[4] [4]Mil-spec AFFFs on QPL Ansul C6 Telomer Foam: 1.1-1.2%F **3M PFOS Foam: 1.8-2.0%F** (~40% reduction in F use) These high purity C6 AFFF agents have been consistently, effectively and reliably in use with the US Military since the 1980's. **C6 fluorosurfactants >99% C6 have been available to foam manufacturers since 2010**[100]**, and many exhibit equivalent and in some cases superior fire performance, as evidenced by some UL polar solvent listings**[101]**.** Since C6 foam agents have vapour sealing and fuel shedding additives providing such similar fire performance as legacy C8 foam agents, there is no evidence to suggest they would not be equally suitable for sub-surface injection. Clearly F3 agents without these critical vapour sealing or fuel shedding additives are **unsuitable for sub-surface injection, and are likely to require significant system design changes to fixed foam systems and their proportioning devices, to accommodate likely higher foam applications rates, particularly on large volatile fuel fires and fuel storage areas.** <u>**This evidence confirms Myth 6 is correct.**</u>
9. Oth: Sect. 1.4, p23 "Myth 7"	*"**Myth:** Modern fluorotelomer foams are "PFOS and PFOA free".* ***Reality:** Largely irrelevant marketing claim – PFOS is a legacy compound; current fluorotelomer foams cannot contain PFOS as a consequence*	<u>**Misleading and incorrect.**</u> **PFOS and PFHxS are only derived from the ElectroChemical Fluorination(ECF) process**[102,135]**.**

<table>
<tr>
<td></td>
<td>of the telomerisation pathway used for chemical synthesis. Free PFOA has not been used in foams for decades, however, 200- 600 PFOA precursors and related homologues are common in formulations or as later transformation products…"</td>
<td>


Fluorotelomer foams do not contain or breakdown to PFOS. PFOA is a breakdown product of long-chain fluorotelomers and ECF process only, not high purity C6 short-chain fluorosurfactants. High purity short-chain ≤C6 fluorotelomer foams contain unintentional minute impurity traces of PFOA (few ppb) from the manufacturing process, but recognized and accepted by US EPA, and European Chemicals Agency. EU REACH Legislation 2017/1000 (June 2017)[45] effective from July 2020, specifically accepts C6 firefighting foam PFOA impurity levels of 25ppb of PFOA, its salts and 1,000ppb for 1 or a combination of PFOA related substances. Firefighting foams already in use (C8 fluorotelomer based) are exempted from this restriction in EU. C6 PFAS cannot breakdown to longer C7 chain-length PFAS (ie PFOA). It normally requires considerable energy under manufacturing processes to build longer PFAS chains.

<u>This evidence confirms Myth 7 is correct.</u>
</td>
</tr>
<tr>
<td>3. FP:

Sect. 1.4, p24
"Myth 8"</td>
<td>"Myth: Fluorine-free foam cannot be used with non-aspirated or in sprinkler systems.

Reality: Certain F3 products have been approved under UL162 for Type III non-aspirated sprinkler applications at the same concentrations and flow rates as AFFF; Queensland Fire & Emergency Service (QFES) has routinely used F3 foam with a non-aspirating standard nozzle and 50mm hose since 2003."</td>
<td><u>Misleading</u>.
Regarding the UL Sprinkler test, the nozzle pressure is so low it permits gentle not forceful application as an unintended consequence[89]. Forceful application is expected and required for any product to be effective and research shows F3s struggle with forceful application onto volatile fuels. (see section 1.3 above).
Regarding QFES I have no doubt this is true, however it is well appreciated that Fire and Rescue Services the world over apply foam through standard non-aspirating nozzles onto small fires, at application rates usually delivering massive over-kill, often in the 10-20L/min/m^2 of fire area. They are also able to direct the non-aspirated spray onto the ground ahead of the flame front, to remove the impact velocity, create an aspirated foam blanket gently rolled onto the flaming fuel surface, effectively as a</td>
</tr>
</table>

		gentle low expansion foam blanket. **This flexibility is not available to any fixed non-aspirated foam spray systems. Frequently pre-engineered vehicle foam spray systems designed and tested to AS5062:2016[103] have to be completely re-engineered when changing from an existing AFFF to a new F3 agent[104]. Existing non-aspirated nozzles are often ineffective with F3 and need changing to aspirated nozzles; application rates with F3 often require increasing; cylinder volumes may need increasing to accommodate extended duration of F3**, required to extinguish the prescribed fire area; pipe diameters may change to permit higher flows and pressures to be used to make the system work using F3[104]. Increased viscosity and pre-mix stability issues with F3s, frequently make reliable mixing of foam into the water to form a stable solution problematic. **This evidence confirms Myth 8 is probably correct.**
3. FP: Sect. 1.4, p24 "Myth 9"	*"**Myth:** Fluorine-free foams suffer from fuel-pickup compared to AFFF with poor burn-back resistance.* ***Reality:** No longer true – foams need to be selected for purpose; there are now products on the market comparable to high quality AFFFs that have an EN1568 1A/1A rating."*	**Factually Incorrect.** **Scientific research confirms F3s suffer fuel pick up problems, contributing to poor burn-back resistance[30,31,32,82] and nothing has changed recently?** So how can this no longer be true? These unique fuel shedding and vapour sealing benefits only derive from fluorochemicals in foams[31,32,82], which explains why fluorinated foams generally outperform F3s, particularly on large volatile fuel fires, where forceful application and fuel in-depth occur. *See Appendix V, p59 para 5 confirming* ***\`At low application rates (approximately 4 l/min/m2), a "gentle" F3 application is recommended due the known "fuel pickup" effect.\`*** How can this suddenly be contradicted in the next but 1 sentence?... ***\`At high application rates (> 4.5 l/min/m2 ), this effect becomes irrelevant.\`*** It doesn't make sense! Fuel pick up and poor vapour sealing are still shown as important weaknesses of F3 agents on volatile fuels, particularly when applied forcefully, but significant differences are still evident when AR-F3 is applied more gently on a polar solvent EN1568-4 fire test comparison with C6 AR-AFFF[30],... Regarding F3 1A/1A EN rating, *see Sect. 1.3 p20 and Myth 1 above.* **This evidence confirms Myth 9 is correct.**
3. FP: Sect. 1.4, p24 "Myth 10"	*"**Myth:** Necessary application rates are much higher for F3 foams.* ***Reality:** No differences for*	**Misleading and factually incorrect.** **As already explained ICAO has diluted its fire test criteria doubling the extinction time from 60secs to 120secs in 2014[12], allowing F3 to pass, when previously F3s failed[87]. Scientific research confirms higher**

<table>
<tr>
<td></td>
<td>EN1568, IMO, ICAO, LASTFIRE, AS5062 vehicles. Plus the potential for far LESS generation of firewater with F3."</td>
<td>application rates for F3 are frequently required including Schaefer's 2008 research[17], also independently confirmed by Hinnant at US Naval Research Labs in 2015[82], and UL 162 standard for fire testing[89].

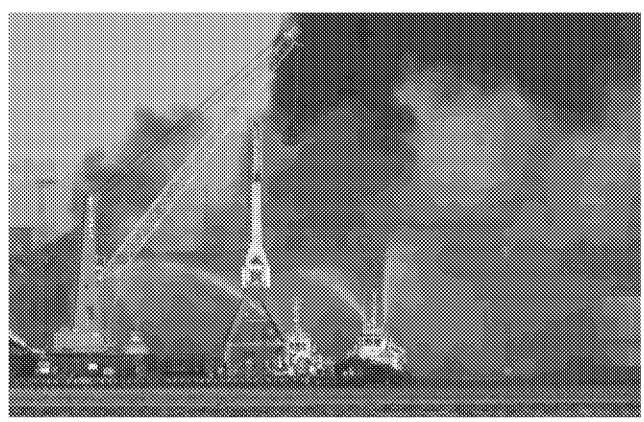
Comparative UL Fire Testing Sweden 2016: Effects of Foam Expansion-F3 v C6 AFFF
F3 = PASS (at 7.5:1) + FAIL (at 4.4:1); C6 AFFF = PASS + PASS (at both 6.9:1 & 3.6:1)
<table>
<tr><th colspan="5">Table 2 : Effects of Foam Expansion: F3 v C6 AFFF</th></tr>
<tr><td>Foam Type</td><td>C6 AFFF</td><td>F3</td><td>C6 AFFF</td><td>F3</td></tr>
<tr><td></td><td colspan="2">Higher Expansion</td><td colspan="2">Lower Expansion</td></tr>
<tr><td>Expansion Ratio</td><td>6.9</td><td>7.5</td><td>3.6</td><td>4.4</td></tr>
<tr><td>Application rate</td><td>7.6L/min</td><td>11.4L/min</td><td>7.6L/min</td><td>11.4L/min</td></tr>
<tr><td>Application time (mins)</td><td>3</td><td>5</td><td>3</td><td>5</td></tr>
<tr><td>90% control time (min:sec)</td><td>1:08</td><td>0:56</td><td>1:26</td><td>1:50</td></tr>
<tr><td>Extinction time (min:sec)</td><td>1:46</td><td>2:10</td><td>2:14</td><td>3:24</td></tr>
<tr><td>Burnback resistance</td><td>5%@5min</td><td>Self-extinct</td><td>10%@5min</td><td>Failed</td></tr>
<tr><td>Litres foam used: 90% control</td><td>8.6</td><td>10.6</td><td>10.9</td><td>20.9</td></tr>
<tr><td>LITRES foam used: Extinction</td><td>13.4</td><td>24.7</td><td>17</td><td>32.8</td></tr>
</table>
Courtesy: Swedish Research Institute/Dafo-Fomtec
Source: Ottesen J-O, & Jönsson J-E, 2017 - AFFF v F3 Foams in Industrial Firefighting Systems – Trends, Performance, Concerns and Outlook, JOIFF Catalyst p7-8, iss3, Jul17, http://joiff.com/wp-content/uploads/2017/07/July_2017.pdf

Sweden 2016 comparative testing (above) <u>confirmed F3 typically requires twice as much foam concentrate to extinguish the UL 162 fire test</u> requiring a higher application rate delivered for longer[85], but delivering 22% slower extinction time than C6 AFFF - and this was at 7.5:1 expansion ratio. <u>A repeat UL162 test at the lower expansion ratio of 4.4:1 similarly doubled the foam concentrate required, but extinction was 52% slower.</u> Hard evidence confirms F3 does not have "potential for less generation of firewater"[3-5,36-39]. In fact it is likely to generate significantly more run-off, plus significantly increased risk of containment overflows sending this polluting firewater runoff into the environment[3-5, 36-39].

<u>This evidence confirms Myth 10 is correct.</u></td>
</tr>
<tr>
<td>3. FP:

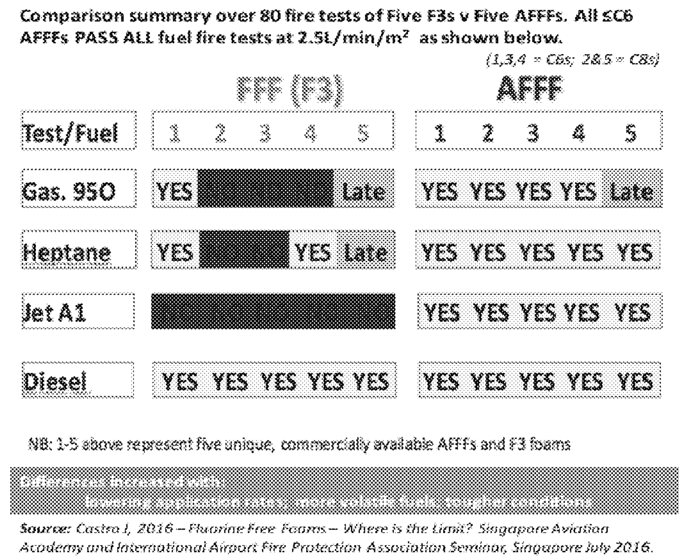
Sect. 1.4, p24 "Myth 11"</td>
<td>Myth: F3 products do not throw as far and cannot be used on deep tank fires.

Reality: Can be solved by operational practice and modern delivery technology such as CAFS (compressed air foam systems)."</td>
<td><u>Misleading.</u>
F3s can throw further using CAFS, as do other foam types, but unaided through standard identical non-aspirated foam nozzles AFFF is likely to throw further, as the fluorochemicals will hold the stream together better[68].
<u>CAFS is also more forgiving of F3 foam quality</u>[75,76]<u>, but operational use of CAFS outside Fire and Emergency Service use for small fires, is likely to require costly large air compressors, and make already difficult logistics even harder to deploy</u> effectively and reliably. It is also difficult to envisage the costly modifications to fixed foam systems, being suitably robust and reliable. Historically several UK Brigades experienced CAFS as difficult to reliably produce the correct foam fluidity they needed and reverted to standard non-CAFs on their trucks.</td>
</tr>
</table>

		<u>This evidence confirms that Myth 11 is correct.</u>
Category: IPEN Section/ Page no.	**Claim?**	**CORRECTION**
1. OpE: Fredericia Port Fire, Denmark, p24	*"The fluorine-free foam blanket has the same durability and burn-back time as AFFF. When it comes to the extinguishing capability of the fluorine-free foam, there are no differences compared to the old [AFFF]. It works exactly in the same way."*	**<u>Misleading and incorrect</u>.** ***See Myths 9, 1,2,& 3 above which correct this statement.*** In this particular Fredericia incident in Denmark[106,107] the differences may have been less marked simply because it seems **<u>no significant volume of volatile fuel was involved</u>, the fuel was only Palm Oil, not classified as a flammable liquid, just a combustible liquid with a very high 162°C flashpoint. Fine water sprays normally extinguish this product, so it is questionable whether F3 was even necessary**[105]. Ironically Palm Oil has even been used as a base for a firefighting foam agents. Interestingly **<u>press coverage focused on the environmental disaster</u>**[106] when reportedly *"12,000 tonnes fertiliser and 2,266 tonnes palm oil were released into the harbour - possibly the biggest environmental catastrophe in Denmark."*  DNF senior adviser Lisbet Ogstrup told Metroxpress. *"In general, monitoring and emergency responses must be dramatically improved."* **According to Ogstrup, <u>the disaster in February "*spilled as much fertiliser into the waters around Fredericia as would normally be seen in an entire year. There is a risk of severe oxygen depletion in an area that is already hard hit by pollutants*</u>,"** she said[106]. A parliamentary majority wanted stricter rules and an explanation from the environmental minister. The Associated Danish Ports authority said **more than 100 people had been deployed in clean-up efforts <u>to remove "*a thick layer of pam oil, water and foam*[107]."</u>** A

		statement said *"a large amount of oil and fertiliser had to be cleared from buildings, quays and roads"*. Somehow IPEN seems to **regard this environmental disaster as an F3 success,** when F3 wasn't strictly required, so unnecessarily added to the BOD loading problem in the harbour? This has similarities with **another environmental disaster where F3 was used at a recent Footscray chemical fire** in Melbourne Australia[3-5,36-39]. *See Myths 1& 3 above.*
3. FP: Sect. 1.4, p25 "Myth 12"	*"**Myth:** Pure C6 firefighting foams have been around since the early 1980s.* ***Reality:** Pure C6 foams have suffered significant performance problems. High-purity C6 fluorotelomer feedstocks were available as early as the early 1980s but pure C6 formulations have only made it to the market for Class B foams with the appropriate approvals in the last 5-6 years. So-called earlier "C6" foams were "C6-based" meaning they had C6 fluorotelomers as a significant component but depended on augmentation by significant amounts (as high as 35-40%) of C8 and higher chain lengths present to achieve the required performance."*	**Incorrect.** **This "Myth" is factually correct.** **A specific high purity 95-97% C6 AFFF (Ansulite) was Qualified under MilF Spec in 1982 and used extensively and effectively alongside other MilF Spec Qualified products for decades[100,128].** It had 40% lower Fluorochemical levels than 3M Lightwater C8 product, but was equally effective[100,128] *-see also Myth 6 above.* **This evidence confirms that Myth 12 is correct.**
3. FP: Sect. 1.4, p25 "Myth 13"	*"**Myth:** F3 foams cannot be used for fires involving 3D-structures, running pool fires, vertical dripping fires.* ***Reality:** Experience in the disaster control industry has shown that there are high quality F3 products available which are perfectly capable of being used for running pool fires as well as large three-dimensional structure fires, especially on vertical surfaces, for example in process plant*	**Misleading.** Most leading firefighting foams can deal with 2D running fuel fires[113]. It is widely accepted that normally aspirated firefighting foams of all types (fluorinated and fluorine free) are not well suited to 3D[108] – pressure fed fires (unless a dual agent response with dry chemical powder is initiated). Any foam type is likely to require additional assistance from dry chemical powder[108], possibly with CAFS foam, to stand any realistic chance of being successful in efficiently extinguishing such complex 3-D fires. **This evidence confirms that Myth 13 is correct.**

ED_002330_00159097-00041

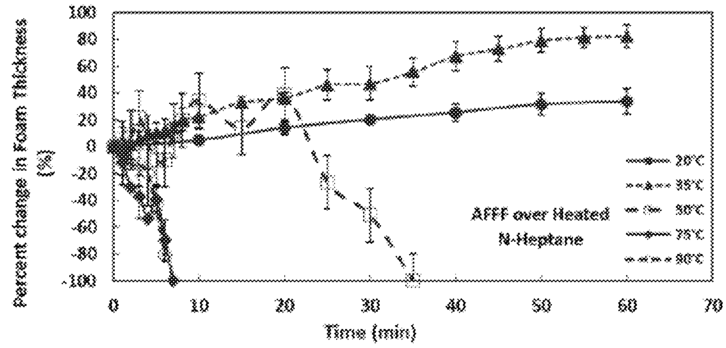
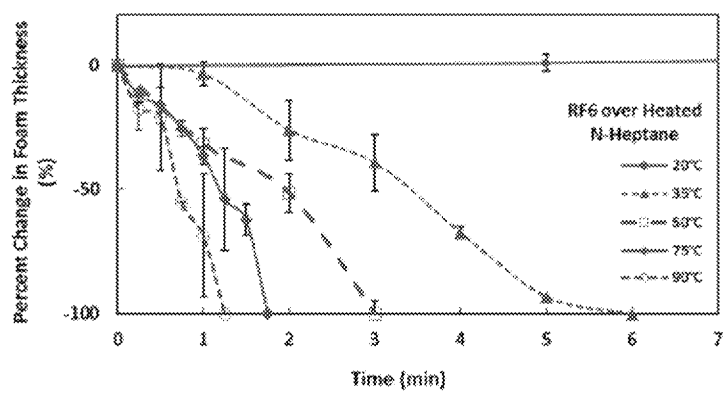
	where film formation is not useful."	
3. FP: Sect. 1.4, p25 "Myth 14"	*"**Myth:** Fluorine-free foams have poor burn-back resistance compared to AFFFs.* ***Reality:** Even early published data with a first-generation 3M RF6 fluorine-free foam showed that burn-back resistance and extinction performance were completely comparable to PFOS-containing AFFF under the conditions of an ICAO Level B test protocol, both types of foam satisfying the requirements "*	**<u>Misleading and incorrect</u>.** **Extensive comparative fire testing in UK 2013[30], Spain[86], Sweden[35], Denmark [87], confirmed C6 AFFF provided 4 times longer burnback on Jet A1 fuel during comparative ICAO Level B fire tests, than F3** with 3 times faster extinction.  None of the five different F3 agents tested in Spain was able to pass the test at 2.5L/min/m2 on Jet A1. *Why not? When this is the application rate for ICAO Level B certification?* C6 AR-AFFF compared with AR-F3 on EN1568 pt 4 Polar Solvent fire test, confirmed the **AR-F3 failed the burnback test after just 58secs (5 mins to pass)**. **AR-F3 also extinguished the fire in 4mins 18 secs failing the test (3 mins to pass).** The C6 AR-AFFF extinguished the fire 3 times faster, using only half the foam volume of AR-F3. It also lasted 11 times longer in the burnback test, easily passing both test elements[30,61]. **Watch it all on the video:** <u>www.youtube.com/watch?v=3MG2fogNfdQ</u> It is unclear what reference is intended, as relevance of ref 4 (PFAA uptake in lettuce) has questionable relevance to a foam's burnback capability. *See also Myth1 above* and watch <u>www.youtube.com/watch?v=IuKRU-HudSU</u> **<u>This evidence confirms Myth 14 is correct.</u>**

ED_002330_00159097-00042

3. FP: Sect. 1.4, p25 "Myth 15"	*"**Myth:** F3 foams do not have the same long drainage times as AFFFs.* ***Reality:** False. Comparisons carried out by Williams et al (2011), working for the US Department of the Navy Naval Research Laboratory (NRL), compared a re-healing foam with two AFFFs and found that the drainage times for the fluorine-free product far exceeded those of the AFFFs."*	**Misleading.** **Drainage time alone is not a reliable indicator of firefighting performance, or burnback resistance of the fire. AFFFs usually have significantly faster drain times than F3s, but superior extinguishment times and burnback resistance, particularly on volatile fuels like gasoline[30-32,85-87]. The 2011 Williams paper referenced[109], confirms F3 drainage time approx. double AFFF, but burnback was 20% less effective on volatile fuel (gasoline).** Comparison AFFF v F3 fire extinguishment times on different fuels (see table below) **Source:** Williams B, Murray T, Butterworth C, Burger Z, Sheinston R, Fleming J, Whitehurst C, Farley J, 2011 - Extinguishment and Burnback Tests of Fluorinated and Fluorine-free Firefighting Foams with and without Film Formation www.nfpa.org/~/media/files/news-and-research/.../supdet11williamspaper.pdf?la=en **Hinnant's research[82,136,137] shows even unignited heptane at 50°C dramatically attacks a well formed F3 blanket in 3 minutes, compared to AFFF which resists attack for 35 mins – 11 times longer.**

Table III: Fire Out Time (s)

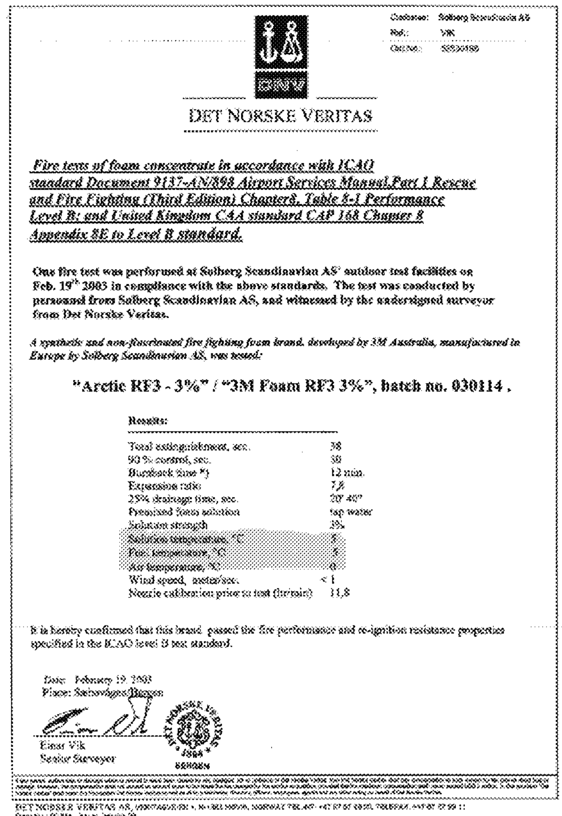
		Foam		
Fuel	**Fuel Surface Tension (dynes/cm)**	**National Type 6**	**Buckeye Type 3**	**RF-6 (Type 6)**
Iso-octane	18.7	32,33 (no film)	32,33 (marginal film)	29,30 (no film)
Heptane	20.0	23,28 (marginal filming)	25 (film)	43 (no film)
MCH	23.6	22,23 (film)	19,20 (film)	33, 46, (no film)
Gasoline	23.7	22 (film expected)	21 (film expected)	35,41 (no film)

		 **Fig. 15.** AFFF foam degradation versus time over *n*-heptane at room temperature, 35, 50, 75, and 90 °C. Initial foam thickness was 1.8–2 cm.  **Fig. 16.** RF6 foam degradation versus time over *n*-heptane at room temperature, 35, 50, 75, and 90 °C. Initial foam thickness was 1.8–2 cm. **Source:** Hinnant et al 2017 – Influence of fuel on foam degradation for fluorinated and fluorine free foams. **AFFF being 90% more effective than F3s. Both foams lasted over 1 hour on water**[82]**.** *See also Myth 1 above.*
3. FP: Sect. 1.4, p26 "Myth 16"	*"**Myth:** Fluorine-free foams have inferior vapour suppression performance under operational conditions.* ***Reality:** A claim apparently seized upon from a single academic paper describing very small-scale flux chamber tests under artificial laboratory conditions."*	<u>**Misleading and incorrect.**</u> **There is much evidence to verify this "myth" is correct**[79,30-32]**.** A combined problem faces F3 agents - delivering slower fire control/extinction (which maintains danger to life safety for longer) and poor resistance to re-ignition, by comparing F3s with AFFFs on the same test <u>www.youtube.com/watch?v=3MG2fogNfdQ</u>. Life safety is placed at increased danger of re-ignition and escalation at any time, even when the fire seems out. F3 cannot be relied upon to prevent sudden and unpredictable re-ignition and re-involvement of the fire, which places life safety at unnecessarily increased danger. Ted Schaefer an author of this IPEN report even confirmed in his own 2007 F3 research[110] that *"**the application frequency of RF6 needs to be increased by two-three times in comparison to the application frequency of AFFF.**"* In his 2008 F3 research[17] he further confirms ***"Under laboratory conditions, with a foam blanket 1-2 cm deep, best-performing FfreeF formulation (RF6) provides about***

		30% of the durability of an AFFF for protection against evaporation of low-flashpoint flammable liquids. We also note in the results the significant differences among FfreeF with almost no sealability of AVGAS vapours offered by the two other formulations." Hinnant[82], Jho[31,32] and Angus Fire[30] independently confirm these findings with their work plus Ottesen 2017, Castro 2016, Resource Protection Int'l 2012[85-87]. *See also Myths 3,9, Fredericia Port, Denmark, 14 &15 above.* **This evidence confirms that Myth 16 is correct**.
Category: IPEN Section/ Page no.	**Claim?**	**CORRECTION**
5. C/S: Sect. 1.4, p26 "Myth 17"	*"**Myth:** Safety Data Sheets (SDSs) provide sufficient information for an end-user to carry out a suitable and sufficient assessment of environmental risk (SSAER) especially for fluorinated foams.* ***Reality:** SDS are mostly inadequate to misleading. With a very few notable exceptions, manufacturers' SDS are inadequate as source material for the end-user to carry out an SSAER (Suitable and Sufficient Assessment of Environmental Risk) or for incident responders to assess and put in place appropriate measures."*	**CORRECT.** **There is a disturbing trend for foam manufacturers to somehow expect ecological information on key ingredients to be an adequate substitution for testing on the specific mixture being provided ie. the specific foam concentrate.** *Why?* Fluorinated and fluorine free manufacturers are equally lacking in this regard. **BUT…**in addition we also find disturbingly that some manufacturers are **not providing any product SDS on their website without declaring who they are as availability is "upon request", which is unacceptable**. Latest SDS with ecological information on all foam products **should be available 24/7 on all manufacturers websites, to facilitate any responders to a foam usage or spillage incident help minimize the adverse impacts immediately** - irrespective of whether they be fire, police, ambulance, regulators, water Cos, or members of the public, as it could help to save lives of casualties, rivers or wildlife. To do so they need immediate and transparent access at all times globally. …*What is there to hide?* …*Why is this not mandated?*
5.C/S: Sect. 1.4, p27 "Myth 18"	*"**Myth:** Published approvals for some fluorine-free foams do not accurately reflect performance.* ***Reality:** Marketing desperation. All foams are required to be independently tested and certified on the basis of product sampled from an unopened as-sold container. This applies to AFFF /FP/FFFP as*	**Misleading and incorrect.** A clear example of an approval that does NOT accurately reflect required performance is **a 2003 ICAO Level B acceptance certificate, issued by a well-respected agency for an F3 product tested under ambient temperature conditions of 0°C and fuel/foam solution temperatures of 5°C[13], well below ICAO acceptance criteria[12].**

much as to F3.
End users should satisfy themselves as to the bona fides of the supplier and reliability of any composition and performance test results."

Lower ambient temperatures reduce the volatility of the fuel, while enhancing the stability of the foam blanket making the test easier to pass. The fire test protocol clearly states ≥15°C, so it fails to meet the test conditions for approval - <u>it has FAILED, yet claims to pass with a certificate</u>. <u>This certificate should NEVER have been issued and is FALSE</u>.


Customer: Solberg Scandinavian AS
Ref.: VIK
Cert.No.: 55530189

DET NORSKE VERITAS

<u>Fire tests of foam concentrate in accordance with ICAO standard Document 9137-AN/898 Airport Services Manual,Part 1 Rescue and Fire Fighting (Third Edition) Chapter8, Table 8-1 Performance Level B; and United Kingdom CAA standard CAP 168 Chapter 8 Appendix 8E to Level B standard.</u>

One fire test was performed at Solberg Scandinavian AS' outdoor test facilities on Feb. 19th 2003 in compliance with the above standards. The test was conducted by personnel from Solberg Scandinavian AS, and witnessed by the undersigned surveyor from Det Norske Veritas.

A synthetic and non-fluorinated fire fighting foam brand, developed by 3M Australia, manufactured in Europe by Solberg Scandinavian AS, was tested:

"Arctic RF3 - 3%" / "3M Foam RF3 3%", batch no. 030114 .

Results:	
Total extinguishment, sec.	38
90 % control, sec.	30
Burnback time *)	12 min.
Expansion ratio	7,8
25% drainage time, sec.	20' 40"
Premixed foam solution	tap water
Solution strength	3%
Solution temperature, °C	5
Fuel temperature, °C	5
Air temperature, °C	0
Wind speed, meter/sec.	< 1
Nozzle calibration prior to test (ltr/min)	11,8

It is hereby confirmed that this brand passed the fire performance and re-ignition resistance properties specified in the ICAO level B test standard.

Date: February 19, 2003
Place: Sotravågen/Bergen

Einar Vik
Senior Surveyor

DET NORSKE VERITAS AS, [illegible]

This same manufacturer produced **a claimed "fuel in-depth 12.8m dia. F3 tank fire" test in Beaumont Texas, 2013**[111]. Using their own data of 1703L (450gal) fuel usage over the 128.7m² surface area of the tank, <u>calculated a fuel depth of just 1.33cm beings used[112], qualifying as a spill fire (NOT fuel in-depth as implied which exceeds 2.5cm). The high application rate used was 10.3L/min/m², *2.5 times NFPA 11's recommended*</u> *4.1L/mim/m² for hydrocarbon spills*. **This Beaumont fire took over 2 mins to extinguish with overkill forceful application, when most spill fire tests require extinction using typically ≤2.5L/min/m² (eg. ICAO, UL162, EN1568-3, MilF Spec).** *Where is the large scale fire testing of F3s to verify small scale test results scale up safely?* These were extensively done with AFFFs and other fluorinated foams (up to 3,000m²) in 1970s-80s[21,66-70], upon which design standards like NFPA11[113] were founded.

<u>Foam users should NOT have to "*satisfy themselves as to the bona fides of the supplier and reliability of any composition and performance test results.*"</u> These products are relied upon to save lives and manufacturers should take pride in them being trustworthy and beyond reproach. **<u>It is the foam manufacturers responsibility to provide honest, fair and representative information...</u>**

		seemingly something also sadly missing from this "IPEN F3 Position Paper". Surprising from supposed "revered experts in their field", who many expected trustworthy! Misleading claims in this document could be placing innocent lives at increased and unnecessary risk. **<u>This evidence confirms Myth 18 is correct.</u>**
3: FP: Sect. 1.4, p27 "Myth 19"	*"**Myth:** F3 foams suffer from fuel pickup and reduced burn-back caused by the presence of hydrocarbon surfactants when used operationally.* ***Reality:** In order to work, all foams need to be appropriately applied in terms of the foam type, equipment used and the training of the firefighters. Fuel pickup for any foam is simply avoided by trained and competent firefighters as part of normal application methods by not using a "plunging jet" foam stream."*	**<u>Misleading</u>.** **Hydrocarbon surfactant based foams containing fluorosurfactant additives do not suffer from fuel pick up and reduced burnback like F3s, because the fluorotelomer surfactants enable them to shed fuel and seal vapours**[17,30-32,82]. In large volatile fuel fires, it is normal to help protect firefighter lives by discharging foam as an aspirated rope from as far away as possible, while applying the foam as gently as possible by bouncing off obstructions. **Inevitably where fuel pools >25mm, there will be some mixing with the foam, it cannot be avoided.** These volatile hydrocarbon fuels are attracted to the bubble structures of hydrocarbon surfactant foams[114], become entrained in the bubbles which can cause the F3 foam blanket to burn[30-32,85-87].  **<u>The USS Forrestal disaster in 1967[71-74], resulted from fluorine free foam without fuel shedding capabilities being unable to control a major fire on this aircraft carrier. 134 people tragically died, 161 were seriously injured, 21 aircraft destroyed and 40 damaged</u>.** AFFFs were fast-tracked for development following this disaster, to try and avoid such carnage happening in future – and it hasn't since by using high performance fluorinated foams. *Why should we risk putting the clock back? See also Myths 1,3,5,14 &15.* **<u>This evidence confirms that Myth 19 is correct.</u>**
3. FP: Sect. 1.4, DFW comparati	*"Recent video footage from comparative tests of an F3 and an AFFF MIL-Spec product on a pool fire at Dallas Fort Worth (DFW) Fire Training Academy*	**<u>Misleading.</u>** *Why is there no confirmation of the fuel used?* It is widely understood DFW routinely trains with propane fuel[51,133], which may behave in a less volatile manner compared to Jet A1 or gasoline. *Perhaps it was even a*

ve testing, p27 para 2	*shown at the recent LASTFIRE conference in Budapest in October 2017 by the DFW Fire Chief Brian McKinney, showed no significant differences in performance between F3 and AFFF. Most notably the particular F3 foam used gave a stable foam blanket without re-ignition even after being disturbed and being exposed to a propane torch."*	*less volatile version of Kerosene or Envirofuel?*, that would now allow F3 to meet the revised 2014 ICAO Level B or C fire test protocol[12], but *could reduce the evident differences between F3 and US MilF Spec qualified foam agents on forceful application to volatile fuels? Presumably it only used freshwater and not seawater testing?*
3. FP: Sect. 1.4 Disturbing foam blanket issue, p27 para 4	*"Disturbing a hot fuel surface covered by a foam blanket, whether by inappropriate application of a forceful foam or water jet, or by other means such as walking through it, would anyway in general be considered at best bad fire service practice, at worst extremely foolish."*	**CORRECT …but Misleading.** *What this clearly does not point out is the potential increased danger to nearby personnel of a sudden flashback or re-involvement due to lack of fuel shedding capability in F3 agents?*[31,32,82]. Plus the **unnecessary inherent increased risk of more likely incident escalation with attendant threat to adjacent tanks/infrastructure or neighbouring sites/communities from choosing F3 usage for such a volatile fuel in-depth application, for which extensive testing and research has shown most F3's are not suitable.** Sometimes it is not possible to avoid firefighters standing in the foam blanket to reach otherwise inaccessible pockets of burning fuel. **Use of F3s puts them at increased unnecessary risk,** when C6 AFFFs are proven not to expose them to flashbacks and re-ignition. *Why would any responsible employer seek to do that?*
4. EI: Sect. 2 Massive BOD potential, p28 para 6	*"Keeping in mind the massive BOD potential of all firefighting foams, even when diluted for application (1%, 3%, 6%) and further diluted on entering a waterway to say 100s of ppm (sewage ~300-400 ppm) then normal dissolved oxygen levels of 6-9 ppm only need to be reduced by a few ppm for fish 'kills' and damage to other biota to be inevitable (see scale below)."*	**Important point.** **…But fails to recognize potentially serious EXTRA environmental damage (and volumes of fish/seafood killed) by 2-3 times more F3 used in a given volatile fuel fire (and potential overflow into rivers), compared to AFFF.** **More F3 agent, which is also 10x more aquatically toxic than AFFF[16,33,34,90], used in any incident will risk higher volumes overflowing and entering rivers and killing more fish, as evidenced by recent Footscray fire[3-5,36-39,124-126] and Fredericia port fire in Denmark 2016[106,107].** *See Appendix V, para 9, p60 "**Depending on the formulation, F3 application might result in a higher biological oxygen demand (BOD) and chemical oxygen demand (COD).**"* …particularly when more foam agent is needed to control the fire with increasing volumes used and increasing risk of containment overflows.

Category: IPEN Section/ Page no.	Claim?	CORRECTION
7. FoF: Sect. 2 Solvent free F3s, p30 para 3	*"The development of solvent-free (SF) firefighting foams – see Appendices (Thierry Bluteau) - substantially reduces BOD and COD, and thus the potential for imposed oxygen stress on the receiving environment, by approximately 40%-60% compared to standard AFFF or F3 products."*	**<u>Misleading.</u>** **1.**These solvents referred to as harmful and irritant refer to neat or 100% solvents, not relatively small concentrations <20% in a concentrate mixture with a high water content. **2.** Removing solvents may reduce BODs, but *what eroding effect does it have on F3's firefighting performance and foam blanket burnback resistacne? Also F3 concentrate stability during long-term storage?* Removing solvents to reduce oxygen stress by 40-60% as claimed, is dependent on equivalent volume of foam agent being used as AFFF, for a given sized fire. **<u>Evidence confirms F3s need 2-3 times more on volatile fuel fires</u>**[17,30,79,81,82,116]. *There is no clear evidence to suggest these solvent free F3s are 2-3 times better than most existing F3 agents in fire performance on volatile fuels?* One might expect the reverse. All this achieves is at best a similar BOD performance to C6 AFFFs, since *current evidence suggests 2-3 times more solvent free F3 will still be required*[17,30,79,81,82,116] *compared to AFFF agents?* **3.**If these solvent free F3s are so "environmentally benign", *why are we shown no comparative aquatic toxicity data or fire performance data to validate their future consideration as leading F3 agents? Why did we not see them submitted for the 2017 Lastfire testing program and doing well against other F3 agents?*
4. EI: Sect. 3, p 31	***Exposure Types in General*** • <u>Acute</u>: Short term (96 hours or less) – Severe effects – Rapid response to toxicant – Mortality endpoint (e.g. LC_{50}) • <u>Chronic</u>: Long-term exposure (> 96 hours) – Mild effect – Gradual response to toxicant – Sublethal endpoints (growth and reproduction are most common) – Examples: Early Life Stage (ELS), partial and complete Life Cycle, and Bioaccumulation Tests.	**<u>Misleading</u>.** **What this does not explain is that <u>acute aquatic toxicity of F3 agents could kill all of a specific organism species by its acute toxicity before any Chronic toxicity effects because they are already dead!</u> Chronic toxicity becomes academic – where will they recover from?** Analytical data confirms F3s typically 10-25x more toxic (L for L of concentrate) than AFFFs (but sometimes up to 200x more toxic than FFFPs for example)[16,33,34,90]. F3s may often require 2-3 times more agent to extinguish a given size fire than AFFFs[30-32,34,79,82,85-87,115,116], making it potentially 20-75x more toxic to organisms in a receiving water body, which could wipe out all fish (or specific organisms) in that lake or river or aquaculture farm in the short-term[97,64,65], also potentially creating very long term chronic effects- because they all died quickly at the acute

		stage and there are no larval stages or eggs left, from which the population could potentially make some recovery. *How is that any "benefit" to the fish/other organisms/ effective functioning of the ecosystem? See also Myths 2 & 3 above.*
6. L: Sect. 3.1 Precautionary Principle, p31	*"The Precautionary Principle … places particular obligations on users, manufacturers and regulators in terms of the product content, allowable uses, management considerations and decision making that are pertinent to any potential for adverse impacts, especially in the long term."*	**Correct.** **…But fails to adequately consider the foam user's Duty of Care to protect life safety, prevent unnecessary damage, community disruption and/or destruction of other nearby properties through preventable escalation.** This similarly requires a precautionary approach. The precautionary principle should also protect the environment from excessive use of strong detergents (F3s) which can cause very high BODs and suffocate all life in waterways, bays or lakes. It should also be proportional to the risk (following a risk assessment) and since the Australian Department of Health's PFAS Expert Panel report in May 2018 has concluded[6] ***"There is no current evidence that supports a large impact on an individual's health."*** **…and** ***"In particular, there is no current evidence that suggests an increase in overall cancer risk.*"**. This position paper and historical considerations like the Queensland firefighting foam policy[59], South Australian PFAS foam ban[80], are likely to have taken a significantly over-precautionary approach due to the overly high uncertainty factors built into those policy positions. ***These Department of Health report[6] and NICNAS human health findings[11] on human health also closely coincide with the broad conclusions of the June 2018 US ATSDR Draft Toxicological Profile for PFAS[119] (see p5-6 Human effects),*** confirming these chemicals are not as harmful as many first assumed, so previous uncertainty factors should be wound back accordingly. Significant test research verifies that F3s are not generally considered adequate or acceptable for large volatile fuel fires in most Major Hazard Facilities (MHFs), because of their lack of fuel shedding and vapour sealing capability[22-24,30-32,34,35,41,45,46]. This places unnecessary increased life safety, sudden flashback and incident escalation risks on MHFs, including life safety of contractors, emergency responders on site, the general public, surrounding sites and the local community[22-24,35,41,45]. Usually these MHFs have adequate fixed foam systems and containment areas designed to operate successfully with fluorinated foam agents in a fire emergency. They should be permitted to continue use of more environmentally benign high purity ≤C6 foam agents as UK Environment Agency, US EPA, EU REACH

		and US Washington State legislation permit[22-2435,41,45]. Larger scale comparative testing seems not to have been conducted for F3s as was the case in the 1970's & 80's for fluorinated foams like AFFFs and FPs[21,66-70] to validate the small scale testing at very large scale with fire areas of several thousand m^2. Large scale incidents also confirmed the total unsuitability of F3 agents at large scale [71-74]. **<u>All foam usage in fire emergencies should be required to be contained, collected and analysed prior to remedial treatment and appropriate disposal (irrespective of foam type being used)</u>[46,59], as the firewater runoff generally contains PFAS from the fire (as the recent Footscray chemical factory fire has shown)[3-5,36-39], and is considered more hazardous than the foam agent being used, particularly if the incident is quickly controlled and extinguished with minimal use of foam and water resources, as supported by UK's Environment Agency[35] and Washington State legislation[22-24].** *See also Myths 1 & 3 above.*
3. FP: Sect. 4, volumes of foam for a tank fire, p33 para 5	*"In order to appreciate the very considerable volume of foam solution and cooling water required to control or extinguish a single large tank fire it is necessary to be aware that an 80-metre diameter storage tank with a surface-area of 5,000 m2 would require:* *• nearly 70,000 litres of foam applied per minute* *• a total of at least 4,000,000 litres of foam* *• use of ~250 tons (250,000 L) of a 6% foam concentrate* *• large quantities of additional cooling water for the tank sides and pipework."*	**<u>Misleading</u>.** *Why is this not referenced to any specific Standard/requirement?* **… The numbers quoted assume a fluorinated foam is being used[113,120,77], NOT an F3, which is unproven and unlikely to control such a large fire.** Such large 80m dia. tanks are normally only used for hydrocarbon fuel storage, so normally a 6% foam would not be required[113]. 3% foams are usual for hydrocarbon fuel storage tanks, or 1x3% AR-AFFFs[113,120,46]. *A 3x6% AR-AFFF would only be used at 6% on much smaller polar solvent or ≥10% Ethanol in gasoline fuel tanks*. 3% AR-AFFF foam concentrate used through monitors would require around 60,000L/min application onto a 5,000m^2 tank fuel surface, requiring 5,400,000L foam solution over 90 mins, ie: 162,000L 3% concentrate under the recommendations of the EN13565-2:2009 Standard[120]. **In 2001 an 82m dia. (5,281m2 fire area) unleaded gasoline storage tank in USA (Norco, Orion refinery, Louisiana) was ignited by lightning[77]. The fuel level in the tank was 8.5 metres. It was successfully extinguished in just 65 minutes using AR-AFFF foam concentrate**, after the foam system was correctly set up and began operation. The tank burned for 12 hours before the foam attack started (*not 2 mins as per Lastfire 11m dia tank test - the largest ever with F3 - in Oct. 2017[75,76]*).Some tank cooling with water was commenced during the foam set up period. This fire was extinguished with AR-AFFF well within the design parameters of EN13565:2 2009. Reports confirm that 2x large capacity monitors (30,000

		L/min & 15,000 L/min) foam monitors were used. After fire control was achieved (about 20-25 minutes into the foam attack) a further 3,785L/min monitor was also used. **The fire was extinguished in 65 minutes**. **106,000L 3% AR-AFFF foam concentrate was used to extinguish the fire.** Another 140,000L of various foams were used to maintain security until the tank was emptied. **Around 25.7 million litres of gasoline was saved**[77]. Much of this foam application (which was not destroyed in the fire) would have been contained in the tank shell and surrounding bunded areas. **Crucially this foam attack**[77] **also prevented incident escalation to nearby tanks, other sites/infrastructure, and was safely and quickly brought under control, without unnecessary risks to life safety of firefighters, other personnel or local communities.** It is not expected this could be achieved by any F3 agent, given their proven vulnerability to fuel pick-up and poor vapour sealing ability, **because they have no specific additives to address these problems.** Neither NFPA11[113], nor EN13565-2[120] foam system standards, make any specific recommendations regarding "large quantities of cooling water being necessary for storage tank fires", so this is misleading. Cooling water would only normally be used to reduce radiant heat on close adjacent tanks, or to prevent the tank on fire from collapsing and releasing its flaming contents into the bund ...and beyond.
9. Oth: Sect. 4, firefighting share of market charts, end p33	*"Fluorotelomer production: Global Market Insights 2016 (firefighting foams 32% in 2015 with total 26,500 t)."*	<u>**Misleading and over-simplistic**</u>. **This Pie- chart fails to address major sectors of fluorotelomer use which are growing, ie: Paints, coatings and resins; electronics, communications; renewable energy; automotive sector, etc. It also fails to address other significant fluorinated gases like NOVEC used in the fire suppression industry.** Traditional uses for stain repellents in carpets are not mentioned (usually combined with textiles accounting for around 55-60% of total fluorochemical market). A large paper sizing seems not included. A readjustment recognizing these other important fluorotelomer usage sectors would substantially reduce firefighting foams importance (currently over-represented), to a more realistic level of around 10-12% of total fluorotelomer use, potentially agreeing with the generally accepted "around 5% of the total fluorochemicals market", as confirmed by UNIDO in 2009[1]. Fluorotemomer based Firefighting foam use is declining as environmental regulations tighten, reduced

ED_002330_00159097-00052

		use for training/system testing and increasing substitution from F3s. Rising fluorochemical consumption in refrigerants/air conditioning, aerosol propellants and foam blowing agents (*not mentioned by IPEN either*), expect to further reduce firefighting foam's overall contribution to the fluorochemicals sector, probably falling back to or below this traditionally accepted 5% level[1,121].
4. EI: Sect. 4, risk of PFAS release "doesn't exist using F3" p34 para 1	*"The risk of release of persistent organic pollutants does not exist with the use of fluorine-free foams and release to the environment where firewater cannot be fully contained is tolerable in an emergency. With fluorine-free foams (F3) discharge to foul water sewers or the environment does not result in long term impacts; moreover, remediation costs are minimal or close to zero with little disruption of or impact on societal infrastructure."*	**Misleading and naive.** Where non-persistent firefighting foam is used in QLD, Australia, the Management of Firefighting Foam Policy[59] requires "***site managers must take all reasonable and practical measures to adequately manage, contain, treat or properly dispose of the foam, firewater, wastewater, runoff from activities or after incidents on the site such that any unavoidable release to the environment is not likely to cause significant environmental harm***." It also defines firewater, wastewater or run-off as "***Any contaminated water generated where water sprays, jets, mists, deluge, monitors or foam generators have been used to extinguish a fire, dilute a contaminant, cool a container or stockpile, blanket a spill with foam,*** *disperse or dissolve a gas or vapour release or wash down a contaminated area.* ***This includes firewater, wastewater or runoff produced during testing, training, maintenance, accidental release or an incident whether or not a fire was involved***[59]." It is most likely in fire events that PFAS from other ubiquitous uses within the fire will contaminate the firewater runoff, even when F3 agents have been used and therefore must be prevented from entering the environment[3-5,36-39]. We also see airport fire training areas where F3 has been exclusively in use for 8 years, still having to collect, contain and remediate all runoff from these fire training areas, whether F3 or water only is used – even when it rains[2], so such runoff will need to be collected, tested, remediated and the separated PFAS incinerated[59,46]. This has not been made clear to potential foam users in this section. The August 2018 **Footscray fire in Melbourne has clearly demonstrated high PFAS levels detected in Stony Creek in the runoff from this Chemical factory incident. EPA VIC confirmed only PFAS-free foams were used in this incident**[3,4], which reportedly took 17 hours to gain fire control, and over 5 days to finally extinguish[36-39]. PFAS chemicals were detected at significantly high levels[5] (**16x recreational water quality acceptance criteria** of <0.7µg/L sum PFOS/PFHxS) in the runoff from the fire, presumably emanating from PFAS containing materials

		(not firefighting foam) on site. **Claiming *"The risk of release of persistent organic pollutants does not exist with the use of fluorine-free foams"* is evidently misleading and invariably incorrect, even at times during training[2].** This situation appears no different from the likely requirements had a significantly more effective C6 AR-AFFF been used[30-35,85-87], but with the addition of minimizing smoke, breakdown products of the fire and runoff from site, by providing significantly faster fire control and extinction, without the ensuing environmental disaster which reportedly killed all life in Footscray's Stony Creek[36-39] and caused an environmental disaster in Denmark's Fredericia Port Fire 2016[106-107]. A 1996 major chemical factory fire and explosion in UK was extinguished in just 4 hours using AR-FFFP fluorinated foam, despite 134 appliances responding & crews monitoring for 34hrs on site[99]. Another chemical complex, fuel depots, major port, industrial units and congested residential areas surrounded this site, but neither escalation nor severe runoff were reported issues. The site was safely handed over to the Health and Safety Executive, within 10 hours of the fire starting[99].
4. EI: Sect. 4.1.2, Buncefield – "…contaminated aquifer still restricting use" p35 para 4	*"…contaminated the Greater London drinking water aquifer with PFAS resulting in continuing restrictions on its use now 13 years later and for some years to come."*	**Misleading and incorrect.** Even during sampling immediately following the Buncefield incident, it was confirmed in the 2006 Buncefield Investigation :3rd Progress Report[122] that "*The Drinking Water Inspectorate (DWI) has established an advisory level for PFOS in drinking water of no greater than 3 micrograms/litre*" and "***It appears unlikely that a lifetime's consumption of drinking water containing concentrations up to 3 micrograms/litre would harm human health. In all cases, the levels at which PFOS has been detected has been below this advisory level.***"

6. L: Sect. 4.1.4, "Washington State legislation", p36	*"In 2018, Washington State passed a state-wide ban or strict controls on products containing PFAS, including firefighting foams, effective after a two-year period of grace."*	**Misleading.** This suggests Washington State legislation applies to all PFAS based firefighting foams - everywhere, which is clearly not the case[22-24]. Originally a complete PFAS foam ban was intended[123], until the House Environment Committee decided to look into it further, and sought **testimony from F3 industry experts**[22,23]. **Solberg's Chief Chemist, Mitch Hubert confirmed that** *"...although suitable for shallow spill fires,* ***when F3s plunge below the surface in fuel in-depth fires it picks up fuel, comes to the surface and actually burns.*** *...We are actively telling* ***people do not train with fluorinated foams,*** *use non-fluorinated foams wherever you can,* ***but maintain the short-chain chemistry AFFFs and AR-AFFFs that need to be used for critical situations like airport rescue firefighting and large catastrophic fuel in-depth fires..."*** His colleague Frank Bateman (ICL-Auxquimia) also stated ***"a whole lot more F3 is needed on big fires which also has environmental concerns, ... tanks are extremely difficult without proper use of fluorinated foams***[22,23]***."*** Resulting legislation, passed 27March 2018 **exempted: oil refineries, fuel terminals, airports, military applications & chemical plants from these PFAS foam restrictions**[24], effective from 1st July 2020 - except for training where F3 use is required from 1st July 2018.
Category: IPEN Section/ Page no.	**Claim?**	**CORRECTION**
8. C/R: Sect. 4.1.6, "Waste foam disposal", p37	*"Fluorinated organic compounds are very difficult to dispose of given that standard treatment methods are completely unable to destroy or capture them and their indefinite environmental persistence means they cannot be left in place to degrade or stored in situations where they may escape in the long term"*	**Misleading and incorrect.** **Current and effective disposal options are available** using Plasma Arc Incineration[58] (NSW) or destruction in cement kiln process (QLD)[57]. **Other options include electrochemical oxidation, reduction or sonolytic destruction.** Numerous proven techniques are available to capture and separate PFAS from soils, surface or groundwater and firewater runoff[47-58]. Technologies proven at commercial scale include **Activated carbon filtration, ion exchange resins, modified clays, bioabsorbent granules, ozofractionatively catalyzed reagent addition (OCRA), nano-filtration and reverse osmosis**[47-58]. **Any F3 used in fire incidents where run-off is produced**[59,46]**, or on fire training areas where PFAS has previously been used (leaching from concrete)**[2] **are likely to require analysis, prior to requiring treatment as**

		above. PFAS chemicals are likely to be contained **in the firewater runoff, as breakdown products from most fires as infrastructural components,** as evidenced by the recent Footscray fire[3-5,36-39] – *see also section 4, p34 para1 & Myth 3 above.*
2. SHE: Sect. 5, Socio-economic costs, p38 para 5	*"For example, Queensland hosts commercial fisheries to the annual value about € 280 million with aquaculture valued at € 66 million and recreational fisheries valued at about € 47 million. In Moreton Bay alone, adjacent to Brisbane, the value of commercial and recreational fisheries to Queensland's economy is between € 28 million and € 35 million per year (2012-14 values)."*	<u>**Naive and misleading**</u>. **It is irresponsible to presume that these economic values are not also substantially at risk from the use of increasing volumes of more aquatically toxic F3 agents likely to be required for a given sized fire, which is more likely to overflow containment areas than C6 AFFFs**[16,18,90]. In so doing, F3 agents would supply **increased BOD levels and aquatic toxicity, quickly suffocating/poisoning fish and shellfish in sheltered bays, rivers and estuaries in QLD and elsewhere around the world where F3 may be used in significant volumes**[33-35,]**. This was recently evidenced in the Footscray fire**[3-5,36-39] **where EPA VIC confirmed** on 1st Sept. 2018 that *"… a range of industrial chemical solvents, detergents and fire soot particles were washed into Stony Creek. The key chemicals detected were phenol (an industrial chemical and cleaning product), polyaromatic hydrocarbons (fire and soot by-products) and a group of chemicals called BTEX (benzene, toluene, ethylbenzene and xylene) which are industrial solvents and found in fuels and oils.* ***The results were very high in Stony Creek on Thursday [30th Aug.] and would have caused rapid death of fish and aquatic life in Stony Creek…" "The chemicals in some cases exceed human health recreational contact guidelines and so the advice is for people to avoid contact with the water and not to consume fish"*** EPA earlier confirmed ***"The firefighting foam used by MFB to combat the factory fire did not contain PFAS."*** 2nd Sept EPA further confirmed[124] ***"With considerable fish deaths occurring, we're urging people again to not eat fish caught in the creek, or 5km north or south of the outlet into the Yarra River as it could pose a risk to heath."*** EPA has confirmed **PFAS was detected in Stony Creek from firewater runoff at levels 16 times the recreational water quality level,** and by 6th Sept. Friends of Cruikshank Park confirmed[125] ***"The Creek is effectively dead at the moment. Our park is a ghost park and this incident has taken away our oasis."*** It appears similar effects were experienced in Denmark's Fredericia Port fire in 2016[106,107]. *See also Sect. 4, p34, para 1 & Myth 3 above.*

<table>
<tr>
<td>4. EI:

Sect. 5 Table 5A, p38</td>
<td>TABLE 5A. SUMMARY OF EFFECTS OF FLUORINATED VERSUS NON-PERSISTENT FOAMS.

<table><tr><th>PFAS persistent foams</th><th>Fluorine-free non-persistent foams</th></tr><tr><td>Specialised treatment and/or disposal for PFAS firewater required by high-temperature incineration as PFAS waste.</td><td>Standard wastewater treatment process, sewer disposal or on-site biodegradation in ponds or irrigation to soils.</td></tr><tr><td>PFAS contaminates all other incident materials such as fuels, combustion products and cooling water.</td><td>Does not interfere in the recovery of fuels or treatment of firewater and combustion products.</td></tr><tr><td>Bund overtopping by excessive firewater generation with release to the environment with permanent pollution of resources by PFAS.</td><td>Firewater generation can be far less with less risk of bund overtopping and only localised and temporary effects if released to the environment.</td></tr></table></td>
<td><u>Confused and incorrect.</u>
Specialised treatment and /or disposal for PFAS firewater runoff is also likely to be required when F3 agents are used because of contamination by PFAS in firewater[3,5,126], and fire training ground runoff[2] (as stated in 2nd point, which also applies to F3 usage). See Sect. 4, p34 para 1 above.
Bund overflows are more likely where more F3 agent is likely to be needed as evidenced by Schaefer's[17,82,110], Jho's[31.32,114,128]. and Hinnant's own research[82] – see also Myths 10 & 14 above. There is no evidence to suggest "firewater generation can be far less with F3" - the reverse is proven as evidenced by 2016 UL testing, Dubai Boeing 777 aircrash[61-63,81] recent Footscray fire[3-5,36-39,124-126], Denmark's Fredericia port fire 2016[106,107] and more. See also Sect. 1.3 p20, Myths 1 & 3 above.</td>
</tr>
<tr>
<td>2. SEH:

Sect. 5 table 5A, p39</td>
<td>"Potential for reputational damage for industry sectors with loss of public confidence and loss of confidence in governments that fail to act."</td>
<td><u>Misleading.</u>
Such reputational damage is equally possible/likely using F3s where:
1. <u>people may die unnecessarily due to F3 use</u>[17,30-32,82,85-87] - where fuel shedding and vapour sealing are considered critical capabilities (lacking in F3) to protect life safety at all MHFs, including airports. F3 is not believed to have been used in any major aircrash where lives have been "in the balance", except perhaps Dubai 2016, but passengers and crew miraculously disembarked before the fire took hold[61-63,81].
2. <u>fires may escalate or re-involve causing extra unnecessary damage, smoke and runoff due to F3 use</u> - from delayed control and extinction by F3 agents without critical fuel shedding or vapour sealing capabilities fire[17,31,32,81,3-5,36-39,124-126].
3. <u>excess firewater runoff may kill tonnes of fish, shell fish and aquatic life due to F3 use</u> [3-5,36-39,124-126]– thereby polluting rivers, potentially unnecessarily harming valuable aquaculture industries and potentially adversely affecting human health. The recent Footscray fire[3-5,36-39,124-126] gives an indication... as does Fredericia Port in Denmark, 2016[106,107]. See also Sect. 5 p38 para 5, Sect. 4 p34 para 1 & Myth 3 above.</td>
</tr>
<tr>
<td>6. L:

Section 5.2 QLD Foam Policy, p39</td>
<td>"As the pollution regulator the Queensland Department of Environment and Heritage Protection (now Environment and Science) was, and is, legally obliged to undertake a balanced consideration of a range of factors when making</td>
<td><u>Correct.</u>
<u>...But key problems and issues have been overlooked</u>[18,59,91,129,130], <u>including</u>:
1. <u>Claims Life safety is paramount</u>, yet increasingly convincing evidence F3 delivers inferior performance to C6 AFFF (not B, not T) ignored.
2. <u>Threat of irreversible damage from fire incident by F3 usage not considered</u>[18,131,132] - only adverse impacts of</td>
</tr>
</table>

	decisions on regulation"	PFAS foam in isolation –assuming F3 has equivalent fire performance which is not the case. **3. Duty of care for fast, effective, efficient incident control to save lives, reduce escalation, reduce smoke/toxins/runoff, community disruption, cleanup and environmental harm is sidelined**[131,132]**.** **4. Creates 2 conflicting regulations** – 1st for foams and 2nd for the 95% of other commercial/consumer fluorochemical uses still disposed of via WWTPs, biosludge & landfill leachate**....*Without addressing all these crucial issues, the REAL problems with PFAS cannot be fixed***[18,131,132]***!***
2.SEH: Sect. 6 Examples of transition, p42	*"Industry had a significant concern that in committing funds to transition from existing C8 foam stocks to C6 purity foams that they may well ultimately be required to transition again to a suitable performing F3 foam when that becomes available. For some operators transition costs were estimated at >$10m so this would represent a significant 'regret spend'."*	**Misleading.** Industry also has similar significant "regret spend" concerns about clean-out and modification of systems to install F3 agents, only subsequently to find in a major incident that it fails to work effectively[46,104] because it fails to shed fuel and fails to suppress vapours adequately, allowing escalation and re-involvement **that may cause unnecessary loss of life, create excessive overflow of containment areas with firewater runoff that could seriously kill aquatic life and poison the environment long term.** *Surely, one major disaster with loss of life using F3 could require replacement with proven more effective, efficient and reliable C6 fluorinated foams for MHFs – a significant regret spend for moving to F3?* This requires a detailed risk assessment and verification process to be conducted by all MHFs before undertaking any rash change to F3 or C6[46,18,104,140,146].
1. OpE: Sect. 6.2 Aviation Rescue and Firefighting (ARFF) p44	*"Fluorine-free foam has no operational problems and performs perfectly in an ARFF setting."*	**Misleading and unproven.** **There has been NO major aircraft fire where F3 has been significantly tested to protect life safety**, *so how can anyone make this claim, with any certainty?* Particularly when the **ICAO level B and C fire tests were significantly diluted (2014)**[12]**, allowing poor quality AFFFs and F3s to pass with 120sec extinction (from 60 secs), Kerosene was added as an optional test fuel (instead of Jet A1) and NFPA 403:2018**[84] **allows a response time of 3 minutes (not 2 mins as previously) and accepts ICAO Level C as somehow "equivalent" to MilF Spec, without any meaningful justification.** The recent Dubai Boeing 777 aircrash[61-63,81] where the aircraft burnt for 16 hours while foam agent was applied …should be raising alarm bells with most airport FireChiefs, …*especially when the final report addressing this lack of fire performance has still not been issued 2 years later?*

ED_002330_00159097-00058

		The Fire Services Compliance Manager at London Heathrow claims in Appendix 3, that F3 has been used "successfully" at 2 aircraft fires. Investigation shows the <u>Boeing 787 in July 2013 was a small electrical fire inside the aircraft while standing unoccupied</u>[139]. <u>A small amount of foam was used externally (probably without effect), but the fire was small, internal and extinguished with halon extinguishers.</u> This could not be considered a major incident, nor an example of operational effectiveness of F3's capability. **An Airbus A321 fire could not be found at London Heathrow, using UK Government Air Accident Investigation data, but a <u>May 2013 Airbus A319 small engine fire was found on landing</u>[138]<u>, where foam was used by Airport Fire and Rescue Service plus London Fire Brigade responding (unclear what foam LFB were using)</u>.** Airbus A319 small engine fire at London Heathrow, 24th May 2013  **Source**: UK Government Air Accident investigation Report 1/2015 on Airbus A319-131, G-EUOE, London Heathrow https://www.gov.uk/aaib-reports/aircraft-accident-report-1-2015-airbus-a319-131-g-euoe-24-may-2013 **The fire was quickly extinguished prior to safe passenger evacuation. Whilst this was a significant incident, May temperatures are quite cool in UK, and it could hardly be claimed as a major performance success, since only a small fire in the right engine was involved.** *See also Myth 4 above.*
1. OpE: Sect. 7 Concluding remarks, p45	*"Current fluorine-free or non-persistent Class B firefighting (F3) foams are now viable operational alternatives to fluorinated AFFF. Quality for quality F3 and AFFF concentrates are comparably priced. Unlike fluorinated AFFFs, fluorine-free (F3) foams do not give rise to environmentally persistent, toxic or bio-accumulative chemically stable end products; there is no*	**<u>Misleading and incorrect.</u>** **There is <u>no evidence to verify F3s are proven viable alternatives</u>[30-32, 82,85-87,136,137] for large volatile fuel incidents[21,66-74], particularly in MHFs where protecting life safety is paramount, providing reliable fuel shedding and vapour control is critical, at the low application rates is dedicated fixed foam systems[46,104,140,146], particularly on volatile fuels like gasoline or Jet A1 and when forcefully applied to fuel in-depth fires or at high ambient temperatures[61-63].** ***Where is the large scale fire test data? Where are the operational "successes"?*** *15 years after modern F3s were made available, where*

permanent environmental pollution with perfluorinated POPs; any contamination is short term and rapidly self-remediates; clean-up and remediation costs are negligible or zero compared to the huge and ongoing costs associated with AFFF contamination;..."

are <u>significant examples of large-scale tests or operational "successes" where these products worked equally effectively, efficiently and reliably on large volumes of volatile fuels as fluorinated foam concentrates</u>?

These 2 charts summarise the major differences between C6 AFFFs and F3 agents in terms of fire performance[114] and environmental impacts[144].

Fire Performance Criteria

Foam Property	Advantage	C6 AFFF	F3
Fuel Repellency *	Yes	Yes	No
Fast Speed Knockdown & Extinction*	Yes	Yes	No
Fuel Shedding	High	High	Low
Fuel Pickup	Low	Low	High
Film Formation*	Yes	Yes	No
Foam spreading on fuel*	Yes	Yes	No
Fuel spreading on foam*	No	No	Yes
Fuel emulsification	Low	Low	High
Flammability of contaminated foam	Low	Low	High
Degradation of contaminated foam	Low	Low	High
Heat resistance of foam	High	High	Low

*Fundamental differences between C6 AFFF and F3 foams

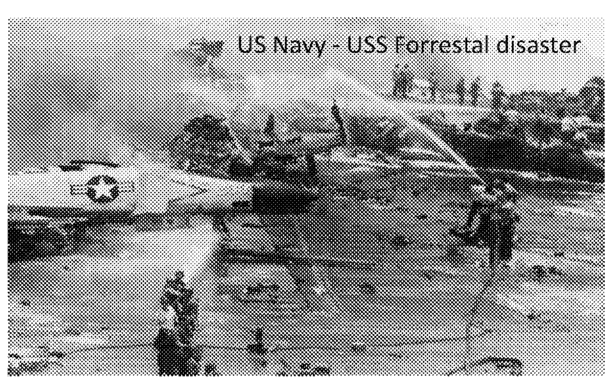
Environmental Impact Criteria

Environmental Property	Advantage	C6 AFFF	F3
Aquatic Toxicity*	Low	Low	10x Higher
Persistence*	No	Yes	No
Bioaccumulation	No	No	No
BOD (Biological Oxygen Demand)	Low	High	High
Reduced foam and water resources use*	Yes	Yes	No
Reduced smoke and breakdown products generated*	Yes	Yes	No
Risk to life safety *	Low	Low	High
Escalation potential *	Low	Low	High
Reduced volumes of firewater runoff*	Low	Low	High
Disposal through Waste Water Treatment Plant (WWTP or POTW)	Yes	Yes (except QLD)	Yes

*Fundamental differences between C6 AFFF and F3 foams

Key Factors for MHFs consideration when choosing a suitable foam:

- **Reducing danger to life safety** with fast fire control and extinction through fuel repellency;
- **Reducing community disruption** by reducing escalation potential;
- **Reducing firewater runoff to collect and contain** with less remediation/treatment/ disposal by reducing volumes of foam usage, water usage
- **Reducing risk of containment overflows**;
- **Reducing smoke and breakdown products**

		generated from the fire as atmospheric and aquatic polllutants; • **Using NON-Bioacumulative, NON-Toxic agents**. *Does it meet all the above criteria?* **Seconds count to save a life. Those same seconds also count in minimizing pollution impacts on our environment**
Category: IPEN Section/ Page no.	**Claim?**	**CORRECTION**
Appendices…	Many of questionable validity.	**Many of these Appendices are similarly riddled with misleading, incorrect and often unsubstantiated statements, like this main document. Therefore this section is highlighting only those Appendix claims where strongly misleading and false claims are being made.**
3. FP, 8.C/R: Appendix 2, p50	*"…so fires can now be effectively extinguished without the use of fluorosurfacants which are a 1960's technology."*	**Misleading and incorrect.** **Fluorosurfactants were developed in the 1960's but still have unique fire performance benefits unsurpassed by any other technology, including modern F3s.** **Since 2006 there have been very significant improvements in more environmentally benign short-chain C6 fluorotelomer surfactants and production processes, which meet the high-purity requirements of US EPA PFOA Stewardship program[41] and the PFOA restriction legislation of European Commission Regulation 2017/1000 (June2017)[45].** **The USS Forrestal disaster in 1967[71-74], resulted from fluorine free foam - like modern F3s today - without fuel shedding capabilities being unable to control a major fire on this aircraft carrier.** 

ED_002330_00159097-00061

	"These water treatment technologies, struggle with short chain PFASs as they are not retained on GAC and break though much more quickly, so GAC is not an appropriate for shorter chain PFAAs. Ion exchange resins can be applied for removal of long or short chain PFASs from water with some being regenerable, but these techniques are not yet widely deployed for treatment of PFASs in impacted waters."	**<u>134 people tragically died, 161 were seriously injured, 21 aircraft destroyed and 40 damaged</u>.** AFFFs were fast-tracked for further development following this disaster, to try and avoid such carnage happening in future – and it hasn't since, by using these high performance fluorinated foams. ***Why should we risk putting the clock back?*** **<u>Misleading and incorrect.</u>** It is not "very difficult" to remove short-chain PFAS.  **Source**: Willson M, 2018 – "Cost-effective ≤C6 Remediation is Achievable", Presented at Ecoforum Australia, 2-4th Oct.2018. Several commercial scale technologies are available -**<u>like this 25,000L/day Ozone fractionative Reagent Addition (OCRA) separation system in use at an Australian Airport to treat firewater training runoff still contaminated with PFOS leaching from concrete</u>** despite changing to f3 8 years ago[2]. **<u>It achieves PFAS removal down to no detect levels (0.002µg/L sum PFAS)</u>** to remove C4-C12 PFAS chemicals from AFFF contaminated firewater runoff, WWTP effluent, surface and groundwater[47-58]. Other technologies are also available for complete destruction of PFAS.
1.OpE: Appendix 3, p55	*"Since purchasing our fluorine free foam, we have used it on 2 separate aircraft fires (an A321 and a 787) and it worked perfectly. Furthermore, the clean-up costs from these incidents were zero"*	**<u>Misleading</u>.** **<u>A large aircraft fire has still not been efficiently controlled and extinguished by any F3 agent.</u>** **The Fire Services Compliance Manager at London Heathrow claims in Appendix 3, that "*F3 worked perfectly in 2 aircraft fires*" and "*the clean-up costs were zero*".** **This seems only because they were small incidents and very little foam was used.** **Air Accident Investigation reports show the <u>Boeing 787 in July 2013 was a small electrical fire inside the aircraft while standing unoccupied</u>[139]. <u>A small amount of foam was used externally (probably unnecessarily and</u> ~~without effect) but no fire penetrated the fuselage. The~~**

ED_002330_00159097-00062

<u>fire was small, internal and extinguished with halon extinguishers.</u> This could not be considered a major incident, nor an example of operational effectiveness of F3's capability. No surprise that clean-up costs were zero.

An Airbus A321 fire could not be found at London Heathrow, using UK Government Air Accident Investigation data, but a <u>May 2013 Airbus A319 small engine fire was found on landing at Heathrow[138], where foam was used by Airport Fire and Rescue Service with London Fire Brigade also responding (it is unclear what foam LFB were using)</u>.

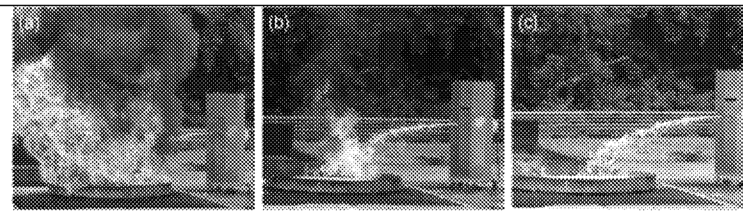
Airbus A319 small engine fire at London Heathrow, 24th May 2013

Source: UK Government Air Accident investigation Report 1/2015 on Airbus A319-131, G-EUOE, London Heathrow https://www.gov.uk/aaib-reports/aircraft-accident-report-1-2015-airbus-a319-131-g-euoe-24-may-2013

The fire was quickly extinguished prior to safe passenger evacuation. Whilst this was a significant incident, May temperatures are quite cool in UK, and it could hardly be claimed as a major fire or major performance success, since only a small fire in the right engine was involved, seemingly requiring little foam agent.

If F3s are so "effective", Why did a planned 2016 Solberg F3 demo of ICAO level B fire test get substituted last minute by a C6 AFFF in 32°C humid Singaporean conditions[61]? Solberg explained because "***too many environmental factors were not under our control to do F3.***" Reportedly the same fire was unable to be extinguished twice using F3 the day before in 32°C conditions, and even caught the fuel separator alight indicating virtually no fire control.C6 AFFF provided progressive control and extinction without edge flickers, despite humid 32°C conditions.

ED_002330_00159097-00063



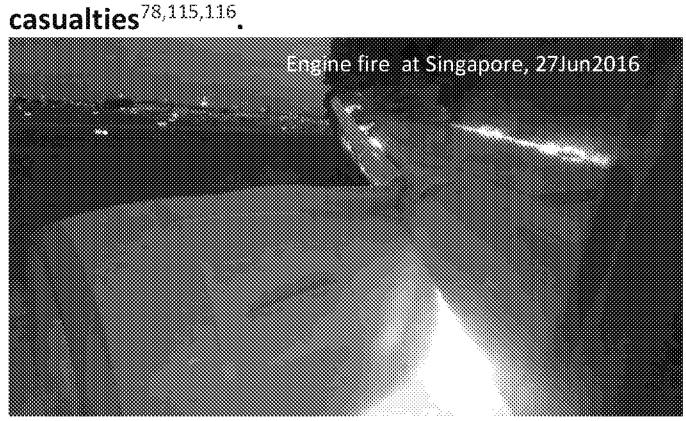
ICAO Level B Fire test demo in Singapore, 2016.
(a) pre-burn; (b) ≤C6 AFFF fire control; (c) ICAO Level B ≤C6 AFFF extinguishment

Demos can be cancelled, real emergencies cannot. Three weeks earlier a major Boeing 777 engine fire at Singapore, was extinguished in 2 mins using fluorinated AFFF/FFFP prior to safe evacuation of all 241 passengers and crew onboard[115, 116].

A disturbing Boeing 777 crash in Dubai 2016 at 48°C, burnt for 16 hours until the airframe was destroyed[61-63].

IPEN's Appendix 1 confirms Dubai International Airport as a major F3 user, apparently since 2011[127], with recent fire truck F3 samples passing routine laboratory testing, strongly suggesting it was used in this Aug2016 B777 crash. *Why is the final investigation report still not issued to explain this firefighting failure - over 2 years later?*

This does not seem to translate into fast, effective and reliable fire control and extinguishment under emergency fire conditions, as occurred swiftly in a Korean Air engine fire in Japan and an engine and wing fire on landing at Singapore, with no passenger or crew casualties[78,115,116].



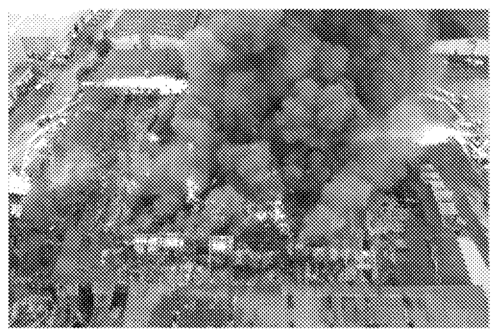
This engine fire at Singapore's Changi airport was rapidly extinguished in 2 mins before all 241 passengers and crew were safely disembarked, using AFFF/FFFP foam agents.

		Where is evidence of F3 major firefighting capability or reliability on large volatile fuel fires, or aircraft fires in the public domain? ***'The problem with remote yet potentially catastrophic risks - they do sometimes materialise, then otherwise very reasonable decisions start to look very UNreasonable, ...even criminal'***
6. L: Appendix 4, p56	*"PHASE OUT PFAS* *The uses of highly persistent, toxic, bioaccumulative PFAS chemicals in applications such as firefighting foam, where there is a very high likelihood of direct release to the envi ronment with downstream social and economic effects, is highly undesirable and is no longer justified or acceptable given that there are low-impact, fully-effective alternatives now available."*	**Misleading and factually incorrect.** **This implies all PFAS are bioaccumulative, and toxic, which is incorrect. It also implies that F3 agents are *"low-impact, fully effective alternatives now available"* to C6 Fluorotelomer alternatives, also incorrect - particularly on large volatile fuel fires and MHFs.** Current changes to PFAS based foam management practices are designed to prevent our PFAS legacy perpetuating[39-42], and Australian Government human health guidance[6] confirms ***"There is no current evidence that supports a large impact on an individual's health."*** from PFAS chemicals ...and ***"In particular, there is no current evidence that suggests an increase in overall cancer risk.*** The Australian 2015 Firefighter study[7] **confirmed increases in Testicular cancer were likely caused by inhalation and skin absorption of volatile breakdown products of the fire (in smoke particularly), some of which are proven carcinogens like Benzo(a)pyrene**, when 79% of all firefighter responses were to structural, vehicle and bush fires where fluorinated foams are not used. It is **misleading to lump all PFAS into the same bucket as proven PBT substances, when short-chain ≤C6 PFAS are categorized NOT Bioaccumulative and NOT Toxic**[10]. NICNAS IMAP 2016 Human Health Tier II C6 Assessment's Occupational and Public Risk Characterisations[11] also co-incides with the Department of Health' Expert panel view, concluding: ***"Therefore, the chemicals are not considered to pose an unreasonable risk to workers' health."*** and ... "***the public risk from direct use of these chemicals is not considered to be unreasonable***." C6 PFHxA has a human half-life of 32days, is excreted through the urinary system[14], and categorized as NOT Bioaccumulative and NOT Toxic[10] (compared to long-chain C8s confirmed PBT with human half-lives of 3.5-8.5

years)[15]

There is **no evidence** suggesting that short-chain PFAS are no longer justified as the fastest and best fire protection available to save lives. Particularly when **a disturbing Boeing 777 crash in Dubai 2016 at 48°C, burnt for 16 hours until the airframe was destroyed.**[61-63] **Strongly suspected of F3 agent being used (*see also Appendix 3 above*). Significantly less AFFF foam usage is also likely to be required in a given size volatile fuel fire incident using C6 AFFF, compared to F3s**[17,30-32,82,136].

The August 2018 **Footscray fire in Melbourne has clearly demonstrated high PFAS levels detected in Stony Creek in the runoff from this Chemical factory incident. EPA VIC confirmed only PFAS-free (F3) foams were used in this incident**[3,4], which reportedly **took 17 hours to gain fire control, and over 5 days to finally extinguish**[36-39].



PFAS chemicals were detected at significantly high levels[5] (**16x recreational water quality acceptance criteria** of <0.7µg/L sum PFOS/PFHxS) in the runoff from the fire, evidently emanating from PFAS containing materials (not firefighting foam) on site. Elevated levels remained for 2 weeks.

Claiming "*The risk of release of persistent organic pollutants does not exist with the use of fluorine-free foams*"(*section 4 p34*) **is evidently misleading and invariably incorrect, even at times during training**[2].

55 million litres of contaminated runoff water had been pumped out of the creek by 3rd day[38], into chemical waste facilities and WWTPs. **This rose to approximately 70 million litres of water and 170 cubic metres of contaminated sediment removed from the creek by 24th Sept 2018**[141].
Victoria's chief environmental scientist Dr Andrea Hinwood said **the incident was "*probably as bad as it could be*" and the chemicals from the fire have had a "*massive*" impact on the system. "*We've had more than 2,000 fish killed,*" she said**[142]. *Let's Remember the foam used was F3 - that IPEN are trying to convince you has*

		no drawbacks, and no remediation costs associated with its use? <u>*See Appendix V para 4, p59 which contradicts this "position" stating* ***"The poorer performance of F3 in this case can be overcome with a higher application rate."***</u> **<u>By contrast, a major UK chemical fire was controlled in 2 hours and extinguished in 4 hrs using fluorinated AR-FFFP[99].</u>** **<u>The UK Environment Agency also concluded in 2014[35]</u>** ***<u>"foam buyers primary concern should be which foam is the most effective at putting out the fire. All firewater runoff and all foams present a pollution hazard."</u>*** This situation **<u>appears worse than the likely requirements had a significantly more effective C6 AR-AFFF been used</u>**[30-35,85-87], providing additional minimizing of smoke, less breakdown products of the fire and **substantially less runoff from site, by providing significantly faster fire control and extinction, without the ensuing environmental disaster** which reportedly killed all life in Footscray's Stony Creek.[36-39] **<u>F3 usage was also implicated in the environmental disaster in Denmark's Fredericia Port Fire 2016</u>**[106-107] (*see comments p 24 above*). **<u>A 1996 major chemical factory fire and explosion in UK was extinguished in just 4 hours using AR-FFFP fluorinated foam, despite 134 appliances responding & crews monitoring for 34hrs on site</u>**[99]. Another chemical complex, fuel depots, major port, industrial units and congested residential areas surrounded this site, but neither escalation nor severe runoff were reported issues. The site was safely handed over to the Health and Safety Executive, within 10 hours of the fire starting[99].
3. FP; 4. EI: Appendix 5, p59	*"The poorer performance of F3 in this case can be overcome with a higher application rate."* *"At low application rates (approximately 4 l/min/m²), a "gentle" F3 application is recommended due the known 'fuel pickup' effect."* *"Depending on the formulation,*	**CORRECT.** **These authors are <u>recognising the limitations of F3,</u> while also recognising the superiority of AFFFs on 2-D fires like hydrocarbon storage tank fires. <u>They also confirm a gentle F3 application is recommended, due to the known fuel pick-up effect.</u>** **This is particularly relevant at low (4L/min.m2) application rates, ...which interestingly most AFFF users do not consider particularly low.**

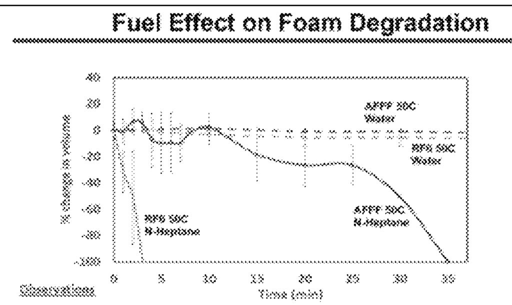
	F3 application might result in a higher biological oxygen demand (BOD) and chemical oxygen demand (COD)."	Correct. Particularly when significantly higher volumes of F3 are likely to be used in major fires, overflowing containment areas thereby spreading more foam and noxious breakdown products of the fire into the environment. At both Fredericia in Denmark 2016[105-107] *(see p24 above)* and the recent Aug 2018 Footscray chemical factory fire in Melbourne[3-5,36-39,124-126,141,142] *(see Appendix 4 above)*. **F3 foam use seemingly contributed to environmental disasters, the like of which does not seem to have been seen in either country previously as confirmed by Environmental authorities.**
3. FP: Appendix 6, p61	*"Although C6 fluorosurfactants have been used for many years by some manufacturers in their formulations it must be accepted that all formulations on the market today are new to some extent and therefore unproven."*	Misleading and incorrect. **It is clearly evident that 95-97% C6 foam agents have been in use since 1981/2 and have achieved Mil F Spec qualification with 40% less Fluorine than 3M Lightwater[100,128].** Ansul Mil-spec (AFC-5&5A)(1981)[(4)] [(4)]Mil-spec AFFFs on QPL Ansul C6 Telomer Foam: 1.1-1.2%F 3M PFOS Foam: 1.8-2.0%F (~40% reduction in F use) These C6 AFFFs have maintained equivalent efficiency, effectiveness and reliability over many decades of use, **alongside long-chain alternatives – they are therefore strongly proven over time – far more so than limited small scale testing of F3 agents has been able to demonstrate.** **Still we wait for any evidence of F3s being effective in any significant large fires, and/or any large-scale testing - which has been done to verify large-scale AFFF performance[21,66-74].** We only hear of significant F3 disasters: Fredericia port 2016[105-107], a burned out plane Dubai, 2016[61-63,81], over 2000 fish killed, and high PFAS levels in Stony Creek from only F3 foam usage at the recent Aug 2018 Footscray Chemical Factory fire[3-5,36-39,124-126,141,142] in Melbourne. *See also Appendix 3 p55, Appendix 4 p56, and Myth 6, p23 above.*
3. FP: Appendix 7, p64	*"I was told that the fluorosurfactants are inert and they should be thought of like 'chemical rocks' that were*	Naïve and Misleading. *Wouldn't you reasonably expect a Chemist to use investigative scientific principles to seek verification of what he is being "told"?...* especially when it relates to

ED_002330_00159097-00068

	stable and non-reactive." *"What I learned from this experience in 1982 is that military aviation fires could be controlled and extinguished by fluorosurfactant free (FFree) firefighting training foam. Effort was made to not be close to the performance of an AFFF, so we purposely held back on performance."*	the reactivity of materials he is using on a daily basis, and when it is well-known that natural chemical "volcanic" rocks do breakdown over time to form sand and sedimentary rocks. **<u>Also Naïve and Misleading.</u>** If Ted Schaefer had to "purposely hold-back on F3 perfromance in the 1980's", why has he been unable achieve significant improvements after nearly 20 years of supreme effort since 2000, when 3M announced their wihdrawal from Fluorochemical manufacture? His own F3 research in 2005[27] idnetified several necessary perfromance challenges which are not achieved, including need to achieve drop in capability; free-flowing like AFFF, re-healing for burnback resistance, none of which have been effectively addressed – particularly where forceful application onto volatile fuels is required, with significantly slower extinction times on small test fires. Jho's 2012 Foam flammability research[31,32,114] confirmed these F3 agents pick-up fuel and burn.  Schaefer in his 2007 research[143] concluded *"The application frequency of RF6 needs to be increased by two-three times in comparison to the application frequency of AFFF". So you need 2-3 times more F3 agent to do the job of an AFFF with 2-3 times higher BOD[18] and 20-30times higher aquatic toxicity than AFFF[16,18,90] when it overflows into the environment?* Schaefer's 2008 research[17] also confirmed *"Under laboratory conditions, with a foam blanket 1-2 cm deep, best-performing FfreeF formulation <u>(RF6) provides about 30% of the durability of an AFFF for protection</u> against evaporation of low-flashpoint flammable liquids. We also note in the results the <u>significant differences among FfreeF with almost no sealability of AVGAS vapours offered by the two other formulations</u>."* These tests were on unignited fuel.

ED_002330_00159097-00069

These findings on F3s were again confirmed by US Naval Research Laboratory in 2015[82], which **also found F3 resisted unignited gasoline vapours even less effectively if the fuel was warm. At 50°C F3 prevented vapour release for only 3 mins, while AFFF lasted 35 mins.** ***This lack of vapour sealing also translates into poor burnback capability as also seen in comparative fire testing by US Naval Research Labs in 2015[82] and others.***[30-32,85,86]



Testimony given by Solberg's Chief Chemist and another Fluorine free manufacturer to Washington State House Environment Committee in Feb 2018 confirmed[22,23] no change, *"...although suitable for shallow spill fires, **when F3s plunge below the surface in fuel in-depth fires it picks up fuel, comes to the surface and actually burns."... "We are actively telling people do not train with fluorinated foams,** use non-fluorinated foams wherever you can, **but maintain the short-chain chemistry AFFFs and AR-AFFFs that need to be used for critical situations like airport rescue firefighting and large catastrophic fuel in-depth fires."***

Does this give you much confidence that** "military aviation fires could be controlled and extinguished by fluorosurfactant free (Ffree) firefighting foam." **...either now particularly ... or even then?

F3s without fuel shedding and poor vapour sealing – place lives at increased risk. We should remember that AFFF development was accelerated after the USS Forrestal aircraft carrier disaster in 1967 **to avoid it happening again. 134 lives tragically lost, 161 injured, 21 planes destroyed and 40 planes damaged, when a protein fluorine free foam – like modern F3 versions – without fuel shedding ability and poor vapour sealing, proved unsuccessful**. *Let's be more cautious before too hastily winding that clock back?*

'The problem with remote yet potentially catastrophic risks - they do sometimes materialise, then otherwise very reasonable decisions start to look very UNreasonable, ...even criminal'

"I can state that

	the Socio-Economic issues relating to the use of fluorosur factants, which are used in AFFF products, are extremely costly to those who are suffering medically and those who have lost their lives due to the associated cancer that has emerged from the release of these chemicals in the environment."	**Misleading.** The 2018 Australian Government Department of Health Expert PFAS Panel Report to the Minister provided human health guidance[6] confirming that "***There is no current evidence that supports a large impact on an individual's health.***" from PFAS chemicals ...and ***"In particular, there is no current evidence that suggests an increase in overall cancer risk.*** The Australian 2015 Firefighter study[7] **confirmed increases in Testicular cancer were likely caused by inhalation and skin absorption of volatile breakdown products of the fire (in smoke particularly), some of which are proven carcinogens like Benzo(a)pyrene**, when 79% of all firefighter responses were to structural, vehicle and bush fires where fluorinated foams are not used. NICNAS IMAP 2016 Human Health Tier II C6 Assessment's Occupational and Public Risk Characterisations[11] also co-incides with this Department of Health' Expert panel view, concluding: ***"Therefore, the chemicals are not considered to pose an unreasonable risk to workers' health."*** and ... "***the public risk from direct use of these chemicals is not considered to be unreasonable***." C6 PFHxA has a human half-life of 32days, is excreted through the urinary system[14], and categorized as NOT Bioaccumulative and NOT Toxic[10] (compared to long-chain C8s confirmed PBT with human half-lives of 3.5-8.5 years)[15] This also ignores the substantial precautionary changes to PFAS based foam management and handling practices implemented since 2006 (Including those occupationally exposed) which are designed to prevent any PFAS legacy issues perpetuating[39-42]. **This does not negate the continuing need for properly controlled use of C6 fluorinated foams for protecting life safety in MHFs worldwide.**
1. OpE: Appendix 9, p67	*" Examples of effective use in large incidents since 2003 include large fuel storage tank (30m) collapse vapour suppression, large-scale oil well blowout fires, fuel terminal tank (15m) fires, container ship fire,*	**Misleading and unsubstantiated.** *Where are the references and incident details for these events to verify efficient, effective and reliable fire protection? How long did control and extinction take? How much F3 foam was used over what fire area, for how long, to enable determination of application rates and effectiveness?*

	aircraft crashes, offshore oil platform and helideck protection and oil refinery fires." *"In 2013 a large petrol spill of over 150,000 L into a bund at a fuel terminal had both AFFF and fluorine-free foam (3F) applied to it to suppress flammable vapours, both foams were found to be effective."* *"Initially FP fluorinated foam (3%) was applied to the spill, fol lowed by fluorine-free foam (6%) from outside resources. Not only was the fluorine-free foam effective in suppressing fuel vapours it did so in spite of being mixed with the FP foam already applied to the spill as well as being applied with airport fire tender equipment not regarded as appropriate for foam application to bund spills."*	We have seen **claims in Appendix 3 p55 above, that "*F3 worked perfectly*" but these were small fires** - one of which seemed ineffective and unnecessary as the air incident investigation report[138] confirmed the fire was **small, inside the fuselage and extinguished with halon extinguishers!** *Are the others similarly misleading?* An interesting contradictory version of the events with which I am familiar. **Both foam can't be equally effective if 6% F3 requires top up every 15-20 mins and a 3% FP resists fuel attack for 90 mins between top ups – both monitored by the same LEL gas detectors**. The **foam users presentation at Hazmat 2014 Conference[79] clearly confirmed that AR-AFFF was used for the first hour, then F3 6% concentrate** requiring top ups too frequently at every 15-20 mins before LEL monitors triggered further top up until 6% F3 ran out. **Only then was Fluoroprotein 3% foam used** from Kurnell Refinery (using only half as much concentrate per top up as 6%) and lasting 90 minutes between top-ups, over 4 times longer than the F3 agent, on this unignited gasoline spill. The figures quoted seem highly questionable too…**There must be some confusion, as we can't both be right! …Clarificstion would be useful for all.**
3.FP: Appendix 10, p69.	*"…most of the commonly used ones [solvents] are either toxic, harmful or irritant. First of all butyl-carbitol (butyl diglycol or BDG) must be reported in the US if spilt; the second reason is that the "safe" alternatives like PG and derivates are more expensive and not that good in firefighting foams; the third reason is that they bring a lot of COD;"*	**Interesting.** Butyl carbitol was a major ingredient in many firefighting foams until it became a reportable substance in US due to toxicity concerns, which I understand has since been rescinded. **It triggered a change to proplylene glycol ethers, which although little better -if at all- environmentally, had less aquatic toxicity data available**, so it provided a convenient alternative. **Some leading manufacturers were able to use the far less toxic hexylene glycols, another reason that leading C6 AFFF technology has significantly lower aquatic toxicity than F3s … as well as having less hydrocarbon surfactants - or detergents - the MOST toxic foam ingredient of all**!
2.SEH: Appendix 12, p72	*It is, therefore, concluded that the responsibility at the present time lies with the client, the IOCs and NOCs* [International and National Oil Cos]. *They undoubtedly have the*	**Confusing.** **Not recognising Oil Cos for their achievements and the difficult dilemmas they face.** My experience is that **Oil Cos are trying their best to do the right thing** - exactly as suggested, **by using and specifying the least environmentally harmful firefighting foam agents that**

	power and influence to ensure that all SOW [Statement of Works] *specifications are written in such a way so as to ensure that the more environmentally damaging foam products are no longer supplied and used. They can also ensure that the supplied product meets the original specification as detailed in the SOW.*	**will reliably do the job needed - protecting life safety and critical infrastructure.** Most have already moved away from PFOS based foams. Leading Cos are **conducting rigorous risk assessments and extensive fire testing** beyond small tray fires to determine and satisfy themselves precisely where modern Fluorine Free foams can be used, within their operations[140]. The Lastfire group is funded by a wide range of Oil Cos. It has been **working to test F3 and C6 foam agents beyond small trays**, into small storage tank fires (11m dia) and bunded areas, while also using CAFS (Compressed air Foam) which was found more forgiving of foam quality[75,76]. One particular F3 performed well ahead of the others, and one C6 was not as good as the other apparently. The results unfortunately have not been released publicly. **There are still concerns about whether such F3s are yet suitable for major tank fires and other high consequence fires in MHFs, where lives may be put at unnecessary increased risk of harm – including airports.** In some **places foam users may also be prevented from doing what they consider is best fire protection for their facilities, because of particularly demanding local environmental regulations**[43-45,59,80,129,130] that do not neccesarily give them the choice. We should therefore **encourage regulators to adopt approaches like that of US Washington State**[22-24], where F3 agents are required for all firefighter training from July2018, and Municpal Fire Department use but fluorinated foams (which have moved to more environmenatlaly benign C6 short-chain technology) are exempted from restriction for front-line firefighting use at Major Hazard Facilities – defined as airports, military applications, oil refineries, petroleum terminals, and chemical plants. *See also Section 4.1.4, p36 above.* This approach recognises that **sometimes major fires materialise which need the best foams we have to be able to control and extinguish them quickly, before more harm occurs and lives may be lost – including minimising environmental harm from the whole incident**.
This concludes the corrections for this MISLEADING IPEN F3 position paper		

References:

1. UNIDO, 2009 - PerFluoroOctane Sulfonate (PFOS) Production and Use: Past and Current Evidence https://www.unido.org/fileadmin/user_media/Services/Environmental_Management/Stockholm_Convention/POPs/DC_Perfluorooctane%20Sulfonate%20Report.PDF
2. Baduel C et al, 2015 - Perfluoroalkyl Substances in a Firefighting Training Ground (FTG), Distribution and Potential Future Release, https://www.researchgate.net/profile/Christine_Baduel/publication/276151390_Perfluoroalkyl_substances_in_a_firefighting_training_ground_FTG_distribution_and_potential_future_release/links/55e7b9a708ae21d099c15634.pdf?origin=publication_detail&ev=pub_int_prw_xdl&msrp=bbVZSR_iYRA8qxCUd8zNXPQ4qvb04fqJ1JZ47Lj1PYz6XuKSp3zr-15tIFxHMojlH7f4BJ9xuz8fjfoEb6ZH-w.K586zRpGT3xjnS63DMN1y-bd5dxAhe3Tv0A5g4ycRffvHZJQHwEZE-6yvhDuh_iewb8IjTuNFv4wqsqvl0JaJg.42lkF_qtvbGO2lB9nqNtCR7TxR5vR1nMXro3r-7chGOfmWTmxrBiAIG7Vi8lA7pUsfg5eHFCOxVGNDqevUvH0w
3. EPA Victoria, 1Sep 2018 – Avoid Stony Creek Water – EPA https://www.epa.vic.gov.au/about-us/news-centre/news-and-updates/news/2018/september/01/avoid-stony-creek-water---epa
4. EPA Victoria, 3Sep2018 – Keep Pets Away from Dead Fish https://www.epa.vic.gov.au/about-us/news-centre/news-and-updates/news/2018/september/03/keep-pets-away-from-dead-fish
5. EPA Victoria, 19Sep2018 – West Footscray/Tottenham Fire – Water Test Results Summary https://www.epa.vic.gov.au/our-work/current-issues/~/media/Images/Our%20work/Current%20issues/WestFootscray/West-Footscray-Fire--Water-test-results-summary---19-September-2018.pdf
6. Department of Health, Australia, 2018 – Expert Health Panel for Per and PolyfluoroAlkyl Substances (PFAS) http://www.health.gov.au/internet/main/publishing.nsf/Content/ohp-pfas-expert-panel.htm
7. Sim M and Glass D, 2014 – Final Report Australian Firefighters' Health Study, Monash University Centre for Occupational and Environmental Health, Dec.2014 http://www.coeh.monash.org/downloads/finalreport2014.pdf
8. UNEP, 2015- Proposal to list PFOA, its salts and PFOA-related compounds in Annexes A, B and/or C to the Stockholm Convention on Persistent Organic Pollutants http://chm.pops.int/Convention/POPsReviewCommittee/Chemicals/tabid/243/Default.aspx
9. UNEP, 2017 – POP Review Committee: Norwegian proposal to list PFHxS as POP. http://chm.pops.int/Convention/POPsReviewCommittee/Chemicals/tabid/243/Default.aspx
10. NICNAS, 2015 – Inventory Multi-tiered Assessment and Prioritisation (IMAP) Environmental Tier II Assessment for Short Chain PerfluoroCarboxylic Acids and their direct precursors, http://www.nicnas.gov.au/chemical-information/imap-assessments/imap-assessments/tier-ii-environment-assessments/short-chain-perfluorocarboxylic-acids-and-their-direct-precursors
11. NICNAS, 2016 - Inventory Multi-tiered Assessment and Prioritisation (IMAP) Human health Tier II Assessment for short-chain Perfluorocarboxylic Acids and their direct precursors https://www.nicnas.gov.au/chemical-information/imap-assessments/imap-group-

assessment-report?assessment_id=1686
12. International Civil Aviation Organization (ICAO), 2014 – Airport Services manual (Doc 9137) Part 1 4th Edition, Rescue and Firefighting, https://www.bazl.admin.ch/dam/bazl/de/dokumente/Fachleute/Flugplaetze/ICAO/icao_doc_9137_airportservicesmanualpart1withnoticeforusers.pdf.download.pdf/icao_doc_9137_airportservicesmanualpart1withnoticeforusers.pdf
13. Solberg, 2003 – ICAO Level B Certificate of Approval for Arctic RF3-3%, batch no. 030114 – issued by DNV 19th Feb 2003.
14. Russell, Nilsson, Buck, 2013 – Elimination Kinetics of PerFlouroHexanoic Acid in Humans and comparison with mouse, rat and monkey, Chemosphere, Sep2013 ISSN 1879-1298 http://www.biomedsearch.com/nih/Elimination-kinetics-perfluorohexanoic-acid-in/24050716.html
15. Olsen G et al, 2007 - Evaluation of the Half-life (T1/2) of Elimination of Perfluorooctanesulfonate (PFOS), Perfluorohexanesulfonate (PFHxS) and Perfluorooctanoate (PFOA) from Human Serum, 2007. http://www.chem.utoronto.ca/symposium/fluoros/pdfs/TOX017Olsen.pdf
16. Plant D, 2016 – Firefighting Foam: The real Question of Sustainability – Civil Aviation Academy Foam Conference, Singapore Airport, 20-22nd July 2016.
17. Schaefer T, et al, 2008 - Sealability Properties of Fluorine-Free Firefighting Foams, University of Newcastle, Australia, Fire Technology Vol 44.issue 3 pp297-309 http://novaprd-lb.newcastle.edu.au:8080/vital/access/manager/Repository/uon:4815;jsessionid=E0140D586B0467E75B68993EBC83A1CA?exact=sm_subject%3A%22vapour+suppression%22
18. Willson M, 2018 – Balancing Performance and Environmental Impacts of Foam, Fire Protection Association Australia Foam Seminars, Sydney(NSW), Melbourne (VIC) and Perth(WA), Jul-Aug2018.
19. Madrid Statement on Poly- and Perfluoroalkyl Substances (PFASs), Issued 13 Oct 2014 at Dioxin Conference, Madrid, Spain. http://greensciencepolicy.org/madrid-statement/
20. Joslin N, 2014 – Firefighting Foam – the Essential Chemistry, Angus Fire Foamlink 3, www.angusfire.co.uk/.../foam_link/003%20Foam%20Link%20Bulletin%
21. Geyer G et al, 1979 –Comparative Evaluation of Firefighting Foam Agents FAA www.dtic.mil/dtic/tr/fulltext/u2/a074490.pdf
22. US Washington State Legislature – Engrossed House Bill Report ESSB6413 outlining testimony which amended the bill, making exceptions for continued Major Hazard Facility usage. http://lawfilesext.leg.wa.gov/biennium/2017-18/Pdf/Bill%20Reports/House/6413-S.E%20HBR%20APH%2018.pdf
23. US Washington State Legislature – Video to House Environment Committee of Testimony regarding proposed PFAS firefighting foam ban across State Jurisdiction, Submissions 15th March 2018. https://www.tvw.org/watch/?eventID=2018021146
24. US Washington State Legislature – Senate Bill 6413, Restrictions on PFAS chemicals in firefighting foams, http://lawfilesext.leg.wa.gov/biennium/2017-18/Pdf/Bills/Senate%20Passed%20Legislature/6413-S.PL.pdf
25. Angus Fire, 2002 –World's First commercially available Fluorine Free Foam (F3 for Class B fires - Syndura, launched and demonstrated at RAF Manston, Kent, UK on 12th June 2002 (arranged by Mike Willson). http://angusfire.co.uk/about/innovation/
26. Angus Fire, 2013 – Firefighting Foam Patent US 8431036B2 https://patents.google.com/patent/US8431036B2/en
27. Schaefer T et al, 2005 – Performance Challenges of Fluoro Free Foams.
28. US Military Specification MiL-PRF-24385F(SH) Amendment 2, 2017 – Fire Extinguishing Agent, Aquepus Film Forming Foam (AFFF) Liquid Concentrate, for fresh and Seawater,

http://quicksearch.dla.mil/Transient/4A6CB9CA234D4766A4F7FF20D0599785.pdf

29. US Congress, 2018 - FAA Re-Authorization Act 2018 3Oct 2018 - HR302 Sect. 332 ARFF https://www.congress.gov/115/bills/hr302/BILLS-115hr302enr.pdf
30. Angus Fire, 2013 – You Tube Comparative video tests "AFFF/AR-AFFF v Fluorine Free Foam (F3)"on ICAL Level B and EN1568-4 tests - evidence faster extinction, superior burnbacks and less agent usage with short-chain C6 fluorosurfactants, www.youtube.com/watch?v=3MG2fogNfdQ
31. Jho C, 2012 – Flammability and Degradation of Fuel Contaminated Fluorine Free Foams, MDM publishing http://www.dynaxcorp.com/resources/pdf/articles/Flammability-IFF.pdf
32. "Flammable firefighting foams! "(You Tube video), 2012 – Laboratory testing to verify fuel pickup of F3 foams, but not AFFFs www.youtube.com/watch?v=IuKRU-HudSU
33. Willson M, 2017 – AFFF Hangar spill: Better outcomes, minimal environmental impacts - International Airport Review iss 06, Nov 2017 https://www.internationalairportreview.com/article/40575/afff-hangar-spill-better-outcomes-minimal-environmental-impacts/
34. Willson M, 2018 – Submission 16 to Joint Standing Committee on Foreign Affairs, Defence and Trade Parliamentary Inquiry: Management of PFAS in and around Defence Bases https://www.aph.gov.au/Parliamentary_Business/Committees/Joint/Foreign_Affairs_Defence_and_Trade/InquiryintoPFAS/Submissions
35. UK Environment Agency (Gable M), 2014 – "Firefighting foams: fluorine vs non-fluorine", Fire Times, Aug-Sep 2014.
36. Melbourne Fire Brigade, 31Aug2018 – West Footscray Fire Under Control http://mfb.vic.gov.au/News/Media-releases/West-Footscray-fire-under-control.html
37. ABC News 7Sep2018 - West Footscray fire warehouse was not registered for chemical storage: WorkSafe http://www.abc.net.au/news/2018-09-07/west-footscray-factory-fire-not-registered-chemical-storage/10201234
38. The Age, 31Aug2018 (5pm update) – Scores of Dead Fish Wash Up after Melbourne factory Fire https://www.theage.com.au/national/victoria/scores-of-dead-fish-eels-wash-up-after-melbourne-factory-fire-20180831-p500z5.html
39. The Age, 1Sep2018 - Arson police investigate cause of West Footscray factory fire https://www.theage.com.au/national/victoria/police-investigate-cause-of-west-footscray-factory-fire-20180901-p5016s.html
40. 3M 2016 – Submission to Australian government Senate Foreign Affairs, Defence and trade references Committee, regarding contamination of Australian Defence force facilities https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Foreign_Affairs_Defence_and_Trade/ADF_facilities/Submissions
41. US Environmental Protection Agency (EPA), 2006 – PFOA Stewardship program Description and invite, http://www.epa.gov/sites/production/files/2015-10/documents/dupont.pdf
42. Fire Protection Association of Australia (FPAA), 2014 – Selection and Use of Firefighting Foams, Information Bulletin-06 v1, June 2014, http://www.fpaa.com.au/media/139872/fpa_australia_-_ib_06_v1.1_selection_and_use_of_firefighting_foams.pdf
43. European Union, 2006 – Directive 2006/122/EC, PFOS restriction from use across EU after 27 June 2011 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:372:0032:0034:en:PDF
44. Environment Canada, 2008 – SOR 2008-178 Perfluorooctane Sulfonate and its Salts and Certain Other Compounds Regulations http://laws-lois.justice.gc.ca/eng/regulations/SOR-

2008-178/page-1.html
45. European Commission (EU), 2017 - COMMISSION REGULATION (EU) 2017/1000 of 13 June 2017 amending Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards perfluorooctanoic acid (PFOA), its salts and PFOA-related substances. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1000&from=EN
46. Fire Protection Association of Australia (FPAA), 2017 – Selection and Use of Firefighting Foams, Information Bulletin-06 v2, January 2017 http://www.fpaa.com.au/technical/technical-documents/information-bulletins/ib-06-v11-selection-and-use-of-firefighting-foams.aspx
47. Horst J et al 2018, - Water treatment technologies for PFAS: The Next Generation https://onlinelibrary.wiley.com/doi/abs/10.1111/gwmr.12281
48. Liu C 2017 - Removal of Perfluorinated Compounds in Drinking Water Treatment: A Study of Ion Exchange Resins and Magnetic Nanoparticles-PhD thesis, University Waterloo, Canada. https://uwspace.uwaterloo.ca/bitstream/handle/10012/12660/Liu_Chuan.pdf?sequence=3
49. Naidu R, 2015 – Submission to Parliamentary Inquiry by Environment, Natural Resources and Regional Development Committee, into CFA Fire Training College at Fiskville, VIC.19th October 2015. https://www.parliament.vic.gov.au/images/stories/committees/enrc/Fiskville_training_college/transcripts/Ravi_Naidu.pdf
50. Customem 2018 – Sustainable Purity – Biochemical Granular Media PFAS Remediation Presentation June 2018. https://www.customem.com/about
51. Evocra (Sykes M) 2018 – Contaminated Site Remediation, Fire Protection Association Australia Foam Seminar Presentation by Evocra, Melbourne, 1Aug. 2018.
52. Evocra (Dickson M) 2018 – Site visit to 2nd smaller Australian Airport case study site, accompanied by M Dickson, Evocra, 23Aug. 2018.
53. Kucharzyk K et al, 2017 – Novel Treatment Technologies for PFAS Compounds: A Critical Review https://www.researchgate.net/profile/Katarzyna_kate_Kucharzyk/publication/319125507_Novel_treatment_technologies_for_PFAS_compounds_A_critical_review/links/5a06590b4585157013a3be77/Novel-treatment-technologies-for-PFAS-compounds-A-critical-review.pdf
54. Gomez-Ruiz B et al 2017 - Efficient electrochemical degradation of poly- and perfluoroalkyl substances (PFASs) from the effluents of an industrial wastewater treatment plant https://www.sciencedirect.com/science/article/pii/S1385894717305740
55. Merino N et al 2016 – Degradation and Removal Methods for PFAS in water https://www.researchgate.net/publication/308491366_Degradation_and_Removal_Methods_for_Perfluoroalkyl_and_Polyfluoroalkyl_Substances_in_Water
56. Gole V et al 2018 - Sono-chemical treatment of per- and poly-fluoroalkyl compounds in aqueous film-forming foams by use of a large-scale multi-transducer dual-frequency based acoustic reactor https://www.sciencedirect.com/science/article/pii/S1350417718301937
57. Geocycle 2018 – Cement Kiln Processing and PFAS Destruction Presentation, 2018
58. Willson M, 2018 – Cost-effective ≤C6 Remediation is Achievable, Presented at Ecoforum Australia, 2-4th Oct.2018.
59. Queensland Department of Environment and Heritage Protection (DEHP), 2016 – Management of Firefighting Foams Operational Policy, Overview: Key operational policy

requirements, February 2017
https://www.qld.gov.au/environment/pollution/management/investigation-pfas/operational-policy

60. Kim S-K, et al 2012 - Wastewater treatment plants (WWTPs)-derived national discharge loads of perfluorinated compounds (PFCs), https://www.sciencedirect.com/science/article/pii/S0304389411014026
61. Willson M, 2016 – Can Fluorine Free Foams (F3) take the fire security heat? International Airport Review, iss 6, p31-35 - Nov 2016. http://www.firefightingfoam.com/assets/Uploads/ARTICLES-/Willson-IAR-6-2016-Can-F3-Agents-take-the-Heat.pdf
62. Gulf Civil Aviation Authority UAE, 2017 - First Interim Statement - AAIS Case No: AIFN/0008/2016 Runway Impact During Attempted Go-Around, Air Accident Investigation Sector https://www.gcaa.gov.ae/en/departments/airaccidentinvestigation/pages/investigationreport.aspx
63. Gulf Civil Aviation Authority UAE, 2018 - Second Interim Statement - AAIS Case No: AIFN/0008/2016 Runway Impact During Attempted Go-Around, Air Accident Investigation Sector https://www.gcaa.gov.ae/en/departments/airaccidentinvestigation/pages/investigationreport.aspx
64. Allied Colloids, UK 1992 – Major Chemical Fire and runoff pollutes 2 major rivers, Health & Safety Executive summary http://www.hse.gov.uk/comah/sragtech/casealliedcol92.htm
65. Allied Colloids, UK 1998 - 24,000 fish restocked in river, http://www.thetelegraphandargus.co.uk/news/8079633.14_000_fish_are_released_in_river/?ref=arc
66. Geyer G, 1973 - Firefighting Effectiveness of AFFF on large fires - National Aviation Facilities Experimental Center www.dtic.mil/dtic/tr/fulltext/u2/774025.pdf
67. Peterson, Jablonski et al, 1967 – Full Scale Fire Modelling Test Studies od “Lightwater” and Protein Type Foams, Naval Research Labs. http://www.dtic.mil/docs/citations/AD0658318
68. Jablonski E, 1978 – Comparative Nozzle Study for Applying AFFF on large Scale Fires http://www.dtic.mil/dtic/tr/fulltext/u2/a058562.pdf
69. Scheffey et al 1994 - Analysis of Test Criteria for Specifying Foam Firefighting, for Aircraft Rescueand Firefighting, FAA Technology Center, https://www.fire.tc.faa.gov/pdf/ct94-04.pdf
70. Nash P & Whittle J 1977 - Fighting Fires in Oil Storage tanks using Base Injection of foam Part 2 - large scale fire tests https://link.springer.com/article/10.1007/BF02308909
71. USS Forrestal, 1967 – Rocket causes deadly fire on aircraft carrier (US) http://www.history.com/this-day-in-history/rocket-causes-deadly-fire-on-aircraft-carrier
72. US Navy (Stewart H), 2004 - The Impact of the USS Forrestal’s 1967 Fire on United States Navy Shipboard Damage Control – PhD thesis - http://www.dtic.mil/dtic/tr/fulltext/u2/a429103.pdf
73. US Navy, 2017 – the Catastrophic Fire on Board USS Forrestal (CVA-59) https://www.history.navy.mil/browse-by-topic/disasters-and-phenomena/forrestal-fire.html
74. US Navy Live, 2012 – USS Forrestal Remembered – Lessons from the tragedy http://navylive.dodlive.mil/2012/07/30/uss-forrestal-remembered-lessons-from-tragedy/

75. Ramsden N, 2017 – In the line of Fire, Industrial Fire Journal iss100,Q3 2017 p14-16, https://issuu.com/hemminggroup/docs/ifj_q3_2017
76. Rutledge R (Caltex), 2018 – Update on Lastfire testing, presentation at Fire Protection Association Australia Foam Seminars, Sydney (NSW) Melbourne(VIC) and Perth (WA), Jul-Aug2018.
77. Persson H and Lönnermark, 2004 –Tank Fires: Review of Fire Incidents 1951-2003, Brandforsk Project 531-021, SP Swedish National Testing and Research Institute (p A32), http://rib.msb.se/Filer/pdf%5C19108.pdf
78. Associated Press May 2016 – Korean Air jet has engine fire in Tokyo, people evacuated safely, http://www.dailymail.co.uk/wires/ap/article-3612055/Korean-Air-jet-apparent-engine-fire-Tokyo-airport.html
79. Caltex, 2014 – Case Study: Banksmeadow Unleaded Petrol Release 2013, FPAA HazMat Conference, Preston Victoria, 14-15May 2014
80. South Australia EPA, 2018 – Environment Protection (Water Quality) Amendment Policy 2018, https://legislation.sa.gov.au/LZ/V/POL/2018/ENVIRONMENT%20PROTECTION%20(WATER%20QUALITY)%20AMENDMENT%20POLICY%202018_30.1.2018%20P%20521/30.1.2018%20P%20521.UN.PDF
81. Kim S-K, et al 2012 - Wastewater treatment plants (WWTPs)-derived national discharge loads of perfluorinated compounds (PFCs), https://www.sciencedirect.com/science/article/pii/S0304389411014026
82. Hinnant K et al, 2015 - "Evaluating the Difference in Foam Degradation between Fluorinated and Fluorine-free foams for Improved Pool Fire Suppression," US NRL, ARL-TARDEC Fire Protection Information Exchange Meeting, Aberdeen Proving Ground, MD, October 14, 2015
83. US Airforce, 2016 – Airforce awards replacement firefighting foam contract http://www.af.mil/News/Article-Display/Article/915057/af-awards-replacement-firefighting-foam-contract/
84. National Fire Protection Association (NFPA) of America, 2018 – NFPA 403 Standard for Aviation Rescue and Firefighting (ARFF) Services at Airports https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=403
85. Ottesen J-O, & Jönsson J-E, 2017 - AFFF v F3 Foams in Industrial Firefighting Systems – Trends, Performance, Concerns and Outlook, JOIFF Catalyst p7-8, iss3, Jul17, http://joiff.com/wp-content/uploads/2017/07/July_2017.pdf
86. Castro J, 2016 – Fluorine Free Foams – Where is the Limit? Singapore Aviation Academy and International Airport Fire Protection Association Seminar, Singapore July 2016.
87. Resource Protection International, 2012 – Fluorine Free Foam (F3) fire tests, Falck Nutec training Centre, Esbjerg, Denmark Report P-1177.
88. Comité Européen de Normalisation (CEN) 2008: European Standard EN1568 Pts 1-4 Fire extinguishing Media – Foam Concentrates https://infostore.saiglobal.com/en-us/Standards/NF-EN-1568-4-2008-1024496/
89. Underwriters Laboratories (UL) 1994 - UL 162 Standard for Foam Equipment and Liquid Concentrates, 7th Edition http://ulstandards.ul.com/standard/?id=162_7
90. Fire Fighting Foam Coalition, 2006 – Special factsheet on Aquatic Toxicity of firefighting Foams, http://www.fffc.org/images/AFFFupdatespecial.pdf
91. Queensland Department of Environment and Science 2018 – Environmental Management of Firefighting foam in Queensland, Presented by Andrew Connor, Executive Director at Fire Protection Association Australia Foam seminar in Brisbane 18th Jan 2018.
92. Korzeniowski S et al, 2013 –Biodegradation, Toxicology and Biomonitoring: AFFF

Fluorotelomer based Short-chain Chemistry, Reebok Conference, Bolton, UK March 2013
93. Chengalis, C.P., Kirkpatrick, J.B., Radovsky, A., Shinohara, M., 2009a -A 90-day repeated dose oral gavage toxicity study of perfluorohexanoic acid (PFHxA) in rats (with functional observational battery and motor activity determinations). Reprod. Toxicol. 27, 342-351
94. Chengalis, C.P., Kirkpatrick, J.B., Myers, N.R., Shinohara, M., Stetson, P.I., Sved, D.W., 2009b -Comparison of the toxicokinetic behaviour of perfluorohexanoic acid (PFHxA) and nonafluorobutane -1-sulfonic acid (PFBS) in monkeys and rats. Reprod. Toxicol. 27, 400-406 http://www.ncbi.nlm.nih.gov/pubmed/19429410
95. Loveless, S.E. et al, 2009 - Toxicological Evaluation of Sodium Perfluorohexanoate. Toxicology 264 (2009) 32–44. https://www.researchgate.net/publication/26695422_Toxicological_evaluation_of_sodium_perfluorohexanoate
96. H. Iwai, M. Shinohara, J. Kirkpatrick, J.E. Klaunig, 2011 - A 24-Month Combined Chronic Toxicity/Carcinogenicity Study of Perfuorohexanoic Acid (PFHxA) in Rats, Poster Session, Society of Toxicologic Pathology, June 2011 https://www.daikin.co.jp/chm/products/pdf/pfoa/PFHxA/16_PFHxA_E.pdf
97. Lenntech, 2015 - Summary of detergent impacts in freshwater ecosystems. http://www.lenntech.com/aquatic/detergents.htm#ixzz3UbwykSGh
98. US EPA, 2016 – PFOA Stewardship Program final report of 2015 goals met, https://www.epa.gov/sites/production/files/2017-02/documents/2016_pfoa_stewardship_summary_table_0.pdf
99. Avon Fire Brigade UK, 1996 – Incident Report Albright and Wilson Fire (Redacted) https://www.ife.org.uk/write/MediaUploads/Incident%20directory/Albright%20and%20Wilson%20-%201996/Incident_Report_Albright_and_Wilson_REDACTED.pdf
100. Kleiner E, 2016 - 40 yrs of Saving Lives: C6 Fluorotelomer Surfactants and their use in Firefighting Foams, Dynax Corporation at American Chemical Society, San Diego, USA, Mar2016 https://ep70.eventpilotadmin.com/web/page.php?page=Home&project=ACS16spring
101. Underwriters Laboratories (UL) 2018 – Online Certifications Directory https://database.ul.com/cgi-bin/XYV/cgifind/LISEXT/1FRAME/srchres.html
102. Houtz E, Higgins C, Field J, Sedlak D, 2013 – Persistence of Perfluoroalkyl Acid precursors in AFFF-Impacted Groundwater and Soil, environmental Science & Technology 2013, 47, 8187−8195 http://pubs.acs.org/doi/abs/10.1021/es4018877
103. Australian Standard AS 5062: 2016 - Fire protection for mobile and transportable equipment. https://infostore.saiglobal.com/en-au/Standards/AS-5062-2016-
104. Hafey C (Chubb) 2018 – AS5062-2016 fire performance testing with F3 foam solutions, presented at Fire Protection Association Australia foam seminars, Melbourne, Sydney and Perth, Jul-Aug 2018.
105. ScienceLab USA, 2005 – Palm Oil Material Safety Data Sheet https://www.sciencelab.com/msds.php?msdsId=9926383
106. Copenhagen Post, 13Apr.2016 - Danish parliament wants more environmental controls in the wake of harbour fire http://cphpost.dk/news/danish-parliament-wants-more-environmental-controls-in-the-wake-of-harbour-fire.html
107. The Independent UK, 28Feb2018 – Denmark accused of keeping quiet over 'Environmental

Disaster' https://www.independent.co.uk/news/world/europe/denmark-accused-of-keeping-quiet-over-environmental-disaster-that-saw-fertiliser-and-oil-pour-into-a6901376.html

108. North Carolina Department of Insurance, Office of the State Marshall, Fire and Rescue Training – Module 5: Fire Fighting Foam Principles and Ethanol-Blended Fuel – Participants Manual http://www.ncdoi.com/OSFM/RPD/PT/Documents/Coursework/Ethanol/Module5_ParticipantManuals.pdf
109. Williams B, Murray T, Butterworth C, Burger Z, Sheinston R, Fleming J, Whitehurst C, Farley J, 2011 - Extinguishment and Burnback Tests of Fluorinated and Fluorine-free Firefighting Foams with and without Film Formation www.nfpa.org/~/media/files/news-and-research/.../supdet11williamspaper.pdf?la=en
110. Schaefer T et al, 2007 – Vapour suppression of n-Heptane with firefighting foams using laboratory flux chamber, https://www.iafss.org/publications/aofst/7/97/view/aofst_7-97.pdf
111. Solberg 2013 - F3 "12.8m Tank Fire Video Test", conducted 12th Dec 2013 in Beaumont Texas, USA https://www.youtube.com/watch?v=0H1v9DVOoaE
112. Willson M, 2016 – Calculations confirming Solberg's Beaumont Texas "simulated tank fire test" is merely a 1.3cm deep spill fire in a tank shell, misleadingly masquerading as a "tank fire".
113. National Fire Protection Association (NFPA) of America, 2016 – NFPA 11 Standard for Low-, Medium-, High- Expansion Firefighting Foam, http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=11
114. Jho C, 2016 – "Interactions of Firefighting Foam with Hydrocarbon fuel – Some Fundamental Concepts", Singapore Aviation Academy-IAFPA Foam Seminar, Singapore, 20-22 July 2016
115. "Dangerous Escape, Boeing 777 engine Fire – The Singapore Enigma" Singapore Airlines SQ368, 27th June 2016, The Flight Channel, Jul2018 https://www.youtube.com/watch?v=x4W6rVZ_oq4
116. Singapore Transport Safety Investigation Bureau, 2017 – Final Report into Boeing 777 engine Fire at Changi Airport on 27th June 2016, https://www.mot.gov.sg/docs/default-source/about-mot/investigation-report/b773er-(9v-swb)-engine-fire-27-jun-16-final-report.pdf
117. Comité Européen de Normalisation (CEN) European Standard EN1568-4:2008 Fire extinguishing Media – Foam Concentrates Low expansion foams for immiscible fuels https://infostore.saiglobal.com/Store/PreviewDoc.aspx?saleItemID=1406007
118. Lastfire Group, 2015 – LASTfire Fire Test Specification -Revision D http://www.lastfire.co.uk/uploads/LFTestSpecRevD-APR2015.pdf
119. US Agency for Toxic Substances and Disease Registry (ATSDR), 2018 - Toxicological Profile for Perfluoroalkyls (PFAS) Draft for Public Comment - June 2018 https://www.atsdr.cdc.gov/toxprofiles/tp200.pdf
120. Comité Européen de Normalisation (CEN) 2009: European Standard EN13565-2 Fixed Firefighting Systems – Foam Systems – part 2: Design, construction and maintenance http://shop.bsigroup.com/ProductDetail/?pid=000000000030234306

121. UK Department of Environment, Food, and Rural Affairs (DEFRA), 2004 – PFOS Risk Reduction Strategy and Analysis of Advantages and Drawbacks. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/183154/pfos-riskstrategy.pdf
122. Buncefield Investigation report, 2006 – 3rd progress report, part 4 Environmental Monitoring, Section 4.5 Impacts on Environment and Drinking Water, May 2006. http://www.total.com/sites/default/files/atoms/file/Buncefield-Third-Progress-Report-090506.pdf
123. Bloomberg News, 14Feb2018 – Washington State nears ban on Toxic Firefighting Foam https://bnanews.bna.com/safety/washington-state-nears-ban-on-toxic-firefighting-foam-2
124. EPA Victoria, 2Sep2018 – West Footscray Fire Update https://www.epa.vic.gov.au/about-us/news-centre/news-and-updates/news/2018/september/02/epa-west-footscray-fire-update
125. Star Weekly 6Sep2018 - Community backlash at West Footscray fire fallout http://www.starweekly.com.au/news/community-backlash-west-footscray-fire-fallout/
126. EPA VIctoria, 1Nov 2018 – West Footscray Fire –Recovery Update https://www.epa.vic.gov.au/our-work/current-issues/industrial-fire-in-west-footscray
127. Dubai Airport, 30Oct2018 – Personal e-mail communication.
128. Jho C, 2018 – "C6 Foams v Legacy C8 Foams and Fluorine Free Foams – What you need to know" Singapore Aviation Academy – 18th IAFPA Aviation Seminar, Singapore, 9-11May 2018.
129. Queensland Department of Environment and Heritage Protection (DEHP), 2016 – Management of Firefighting Foam Policy's Explanatory Notes, July 2016 http://www.ehp.qld.gov.au/assets/documents/regulation/firefighting-foam-policy-notes.pdf
130. Queensland Department of Environment and Heritage Protection (DEHP), 2017 – Management of Firefighting Foams Operational Policy, Overview: Key operational policy requirements, February 2017 https://www.qld.gov.au/environment/pollution/management/investigation-pfas/operational-policy
131. Willson M, 2017 – Queensland's "Management of Firefighting Foam" Policy – Part 1, Asia Pacific Fire Magazine, iss 60, January 2017. http://apfmag.mdmpublishing.com/queenslands-management-of-firefighting-foam-policy-part-1/
132. Willson M, 2017 – Queensland's "Management of Firefighting Foam" Policy – Part 2, Asia Pacific Fire Magazine iss 61, April 2017. https://apfmag.mdmpublishing.com/queenslands-management-of-firefighting-foam-policy-part-2/
133. McKinney B, 2016 – The Future of Foam in USA, Dallas Fort Worth Airport, IAFPA – Singapore Civil Aviation Academy Foam Conference, Singapore, July 2016.
134. Military News, 27Jun2018 – Swap Complete: Airforce protects Airmen, Environment with new firefighting foam https://www.militarynews.com/peninsula-warrior/community/swap-complete-af-protects-airmen-environment-with-new-firefighting-foam/article_ba855d8a-7a50-11e8-8e35-339620adeb7f.html

135. Korzeniowski S, 2007 – "Fluorotelomer Products in the Environment– An Update" 3rd Reebok Foam Conference, Bolton UK, 3Sept. 2007.
136. Hinnant et al, 2017 – Influence of Fuel on Foam Degradation for AFFF and Fluorine Free Foams https://www.researchgate.net/publication/314107949_Influence_of_fuel_on_foam_degradation_for_fluorinated_and_fluorine-free_foams
137. Hinnant et al, 2017 – Measuring Fuel Transport through AFFF and Fluorine Free Firefighting Foams https://www.sciencedirect.com/science/article/pii/S0379711217301352
138. UK Government 2015 – Air Accident Investigation Report on Accident to Airbus A319-131, G-EUOE London Heathrow Airport, 24th May 2013, Report 1/2015 https://www.gov.uk/aaib-reports/aircraft-accident-report-1-2015-airbus-a319-131-g-euoe-24-may-2013
139. UK Government 2015 – Air Accident Investigation Report on Serious Incident to Boeing 787-8, ET-AOP London Heathrow Airport, 12th July 2013, Report 2/2015 https://www.gov.uk/aaib-reports/aircraft-accident-report-2-2015-boeing-b787-8-et-aop-12-july-2013
140. Rutledge R (Caltex), 2018 – "Caltex case study, a risk based approach to foam transition", presentation at Fire Protection Association Australia Foam Seminars, Sydney (NSW) Melbourne(VIC) and Perth (WA), Jul-Aug2018.
141. Melbourne Water 24Sep18 – Stony Creek Clean-up works https://www.melbournewater.com.au/what-we-are-doing/works-and-projects-near-me/all-projects/stony-creek-clean-works
142. ABC News 13Sep18 – Stony Creek pollution form warehouse fire "as bad as it could be" https://www.abc.net.au/news/2018-09-13/stony-creek-looks-dead-after-pollution-warehouse-fire/10238724
143. Schaefer T et al, 2007 – Vapour suppression of n-Heptane with firefighting foams using laboratory flux chamber, https://www.iafss.org/publications/aofst/7/97/view/aofst_7-97.pdf
144. Willson M, 2016 – Uncertainty Around Firefighting Foams: Minimising Future Environmental Issues, ECOFORUM Conference, Freemantle, Australia, 26-28 October 2016.
145. Jensen-Hughes, 2018 – An Overview of Firefighting Foams: Past, present and Future. Foam technical symposium 2018 https://www.jensenhughes.com/wp-content/uploads/pdf/Fluorinated-Firefighting-Foams-Jensen-Hughes.pdf
146. Firefighting Foam Coalition, 2016 – Best Practice Guidance for Use of Class B Firefighting Foams http://fffc.org/images/bestpracticeguidance2.pdf

***